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ASSESSMENT OF MAINTENANCE SAFETY CLIMATE IN U.S. NAVY FLEET LOGISTICS SUPPORT WING SQUADRONS

by

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September 1999

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Despite Naval Aviation's success in cutting its Class A Flight Mishap rate in half each successive decade between 1950 and 1990, the proportion of aircraft losses attributable to human error has remained relatively constant during the last decade. From Fiscal Years 1990 through 1998, maintenance error was a causal factor in approximately one out of every five Class A Flight Mishaps. Presently there is an on-going effort to identify and systematically reduce factors contributing to human error in Naval Aviation maintenance. This study administers Baker's (1998) Maintenance Climate Assessment Survey (MCAS), which evaluates factors contributing to high reliability, to nearly 1000 participants from the Naval Fleet Logistics Support Wing (FLSW). The purpose of this study is to assess maintainer perspectives of maintenance operations and safety culture within their respective communities. This study finds statistically differentiable responses among the aircraft communities that comprise the FLSW; differences that potentially will help in identifying and developing intervention strategies to further reduce human error in aviation maintenance. Additionally, a proposed list of MCAS questions is produced for fleet wide distribution.

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ASSESSMENT OF MAINTENANCE SAFETY CLIMATE IN U.S. NAVY FLEET LOGISTICS SUPPORT WING SQUADRONS

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ABSTRACT

Despite Naval Aviation's success in cutting its Class A Flight Mishap rate in half each successive decade between 1950 and 1990, the proportion of aircraft losses attributable to human error has remained relatively constant during the last decade. From Fiscal Years 1990 through 1998, maintenance error was a causal factor in approximately one out of every five Class A Flight Mishaps. Presently there is an on-going effort to identify and systematically reduce factors contributing to human error in Naval Aviation maintenance. This study administers Baker's (1998) Maintenance Climate Assessment Survey (MCAS), which evaluates factors contributing to high reliability, to nearly 1000 participants from the Naval Fleet Logistics Support Wing (FLSW). The purpose of this study is to assess maintainer perspectives of maintenance operations and safety culture within their respective communities. This study finds statistically differentiable responses among the aircraft communities that comprise the FLSW; differences that potentially will help in identifying and developing intervention strategies to further reduce human error in aviation maintenance. Additionally, a proposed list of MCAS questions is produced for fleet wide distribution

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EXECUTIVE SUMMARY

Despite Naval Aviation's success in cutting its Class A Flight Mishap (FM) rate in half each successive decade between 1950 and 1990, the number of aircraft losses attributable to human error has remained relatively constant in the last decade. In attempting to meet its stated goal of cutting the Naval Aviation's Class A FM rate attributed to human factors in half by FY2000, the Human Factors Quality Management Board's (HFQMB) initial focus on aircrew error has generated positive results. Since the HFQMB's inception in 1996, the U.S. Navy Class A FM rate dropped to its lowest point in FY 1997 and the U.S. Marine Corps posted its lowest rate in FY 1998. Unfortunately, the singular focus on reducing aircrew error has failed to attain the overall goal. Over the past decade, approximately one in five Naval Aviation Class A FMs were determined to have maintenance error as a casual factor. The HFQMB's prior success, coupled with a Naval Air Systems Command drive to address ongoing aircraft maintenance issues, has compelled the HFQMB to further analyze aviation maintenance in order to assist in reaching its stated goal.

The HFQMB is currently shifting gears to aviation maintenance and has established a Human Factors in Maintenance and Material (HFMM) Process Action Team (PAT). The HFMM PAT adapted the HFQMB's three-pronged approach to further analyze maintenance-related errors and to find systems or processes to eliminate them. The three-pronged approach included extensive mishap data analysis, benchmarking, and a climate assessment survey. The PAT's initial concentration was on major Class A mishaps and common latent conditions that contributed to the active failures that caused major Maintenance Related Mishaps (MRM). Schmorrow applied a maintenance

extension to the Human Factors Analysis and Classification System (HFACS) while examining 470 Naval Aviation MRMs in order to identify the most likely forms of maintenance error and the conditions associated with those errors. The HFACS maintenance extension categories of error-- squadron, violation, unforeseen, and crew resource management -- were found to be the most significant contributors in terms of cost. In analyzing 124 Naval Aviation incidents, which occurred during FY90-FY98, Teeters discovers two initial areas for immediate consideration: contractor related incidents and those incidents with procedural violations. The PAT also benchmarked other organizations and programs, which soon led to the creation and implementation of the Groundcrew Coordination Training (GCT). Lastly, the Maintenance Climate Assessment Survey (MCAS) was created and implemented in order to gain valuable insight into the maintenance community's perception of its safety climate and culture.

This thesis is the final piece of the mishap data analysis, benchmarking, and climate assessment tripod currently being conducted at the request of the Commander, Fleet Logistic Support Wing. The study has nearly 1000 participants from three different aircraft communities that comprise the FLSW. The results of this study conclude that the MCAS can be utilized as a tool for effectively capturing an aviation maintainer's perceptions of safety in maintenance operations. Through analysis of the MCAS it is found that the components of Cummunication/Functional Relationships and Risk Management pose the most immediate concern to the aviation maintainers within the FLSW. Thus, these areas would serve as good starting points for mitigating risk in aviation maintenance operations. Overall, the general safety climate of the FLSW is

assessed to be good; however, some potential areas within each community have been identified for focusing and prioritizing safety intervention efforts.

Through Analysis of Variance (ANOVA) and Multiple Comparison testing this study shows that the mean responses of the C-9 community are statistically different than the mean responses of both the C-130 and C-20 aircraft communities that comprise the FLSW based upon a model of High-Reliability Organizations (HROs). Some generalized observations can be made in analyzing the Model of Organizational Safety Effectiveness (MOSE) component mean responses. Almost across the board the C-9 community's mean responses to questions are noticeably higher than those of both the C-130 and C-20 communities. Moreover, the culture of the C-130 maintenance community is very sensitive to questions that pertain to issues of being over-committed, under-manned/under-staffed, burdening disproportionate workloads, the eroding effects of personnel turnover, and the negative impact of collateral duties acting upon maintenance safety. The old adage of accomplishing more with less seems to have worn thin within the C-130 maintenance community. Additionally, the C-20 maintenance community seems to express concern with coordination, functional relationships, and communication related issues. Lastly, statistical significance is also found along the MOSE components which may also assist in helping to prioritize intervention efforts within the FLSW.

Naval Aviation does not need to wait until another aircraft mishap occurs until it attempts to understand what is going on within the safety climate/culture of its squadrons. The MCAS is best suited to be utilized as a proactive tool by Squadron Commanders and Aviation Safety Officers (ASOs) to identify, prioritize, and focus their safety intervention efforts in order to continue to reduce human error in aviation maintenance operations.

Lastly, a proposed revised set of MCAS questions is enclosed for future use by Commanders and ASOs as a tool to identify the most urgent process problems in ongoing aviation maintenance operations.

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of the Fleet Logistics Support Wing; your sacrifices and dedication are greatly appreciated… keep up the good work.

Lastly, I would like to dedicate this work in memory of my mom, Ruth Ann Goodrum, who unexpectedly passed away during the course of this study. My mom had dedicated her life to education; she had spent 33 rewarding years teaching in the Iowa public school systems and had only retired from teaching less than a week before the tragic heart attack that eventually claimed her life. I guess you could say that Mom lived to teach; I know that she proudly would. Mom taught Dad, Joe, Judith, and I and so many others whose lives that she touched so much about life, respect for others, and love. Mom also taught her granddaughters about the love of books. Mom, we all miss you so very, very much. I thank and praise God that we have been fortunate enough to have known you and love you. Mom, forever and ever, until we meet again… I LOVE YOU.

I. INTRODUCTION

Despite Naval Aviation's success in cutting its Class A Flight Mishap (FM) rate in half each successive decade between 1950 and 1990 (NPS, School of Aviation Safety, 1998), the proportion of aircraft losses attributable to human error has remained relatively constant in recent years (Nutwell & Sherman, 1997). Following the tragic 1996 Nashville, TN F-14 mishap, senior Naval Leadership established a Human Factors Quality Management Board (HFQMB) with a goal of cutting Naval Aviation's Class A FM rate attributed to human error in half by Fiscal Year (FY) 2000 (HFQMB, 1997). In an attempt to meet this goal, the HFQMB focused initially on aircrew error, which was found to be a causal factor in three out of every five Class A FMs. Using an approach similar to that in investigating aircrew error, the HFQMB have since expanded their focus to investigating human factors maintenance-related errors. This thesis contributes to this investigation by capturing the maintainers' perspectives of risk management, safety climate and culture within the aviation maintenance community.

A. OVERVIEW

The HFQMB's (1997) strategy consists of concentrated effort in three areas of evaluation: (1) Mishap Data Analysis, (2) Organizational Benchmarking, and (3) Command Safety Assessment. The objective of analyzing mishap data is to identify the human factors issues in past Class A FM cases. The HFQMB identify both aircrew and supervisory error as major contributing factors. The subsequent analysis allowed the HFQMB to prioritize the intervention target areas based upon prevaling human errors

contributing most to FMs. The benchmarking effort uncovers the best practices and processes utilized in other aviation organizations such as the commercial airlines use of line oriented flight training. In short order the Aircrew Coordination Training (ACT) program was being targeted to give aircrews a means to perform Computer Aided Debriefs (CADs) following aircrew simulation training (Nutwell & Sherman, 1997). Finally, a Command Safety Assessment Survey (CSAS), based on a model of high reliability organizations (Libuser 1994; Roberts 1990) was developed to assess a command's safety climate from an aircrew perspective (Ciavarelli & Figlock, 1997). The survey's results indicated that organizational and supervisory issues were seen as impacting flight safety (Nutwell & Sherman, 1997). Since the HFQMB's inception the U.S. Navy Class A FM rate dropped to its lowest point in Fiscal Year 1997 (Naval Safety Center, 1997) and the U.S. Marine Corps posted its lowest flight mishap rate in Fiscal Year 1998 (Naval Safety Center, 1998). These advances have been attributed to the HFQMB's primary focus and efforts to reduce aircrew error, however the proportion of mishaps attributable to human error has remained relatively the same (Naval Safety Center, 1999).

In early 1999, the Vice Chief of Naval Operations reaffirmed the drive to systematically reduce human error and established a new objective of reducing related mishaps from current levels by 50 percent at the end of FY2000 (T. Meyers personal communication, January 8, 1999). However, only limited success in reducing human error related aviation mishaps can be expected if only aircrew error is being addressed. The HFQMB's success, coupled with a Naval Air Systems Command drive to address

ongoing aircraft maintenance issues (Lockhardt, 1997), compelled it to start examining the maintenance factors that lead to one out of every five Class A FMs.

The HFQMB, in expanding their focus to include aviation maintenance, formed a Human Factors in Maintenance and Material (HFMM) Process Action Team (PAT). The HFMM PAT elected to adapt the same three-pronged approach utilized in examining aircrew factors; and its initial concentration was on 63 major maintenance-related Class A mishaps and the common latent conditions that "set the stage" for active failures that cause them (Schmidt, Schmorrow & Hardee, 1998). The results of their study indicate that supervisory and climate/cultural issues play a direct role in maintenance-related mishaps. Schmorrow (1998) then studies 470 Naval Aviation MRMs ranging from mishaps to more routine incidents in order to identify the most common forms of maintenance error and the conditions associated with them. Utilizing the same analytical process he again found that supervisory and climate/cultural issues play a significant role in maintenance error.

Early maintenance benchmarking initiatives uncovered a maintenance resource management program for maintainers similar to the cockpit resource management program for aircrew. A Naval Aviation Groundcrew Coordination Training (GCT) program was developed and tested producing promising results (Sian, 1997). The GCT proved to be a meaningful training program in which participants learned, as measured by a content-knowledge test, valuable information that affected real changes in behavior and attitudes. Additionally, a three-month follow-up to the GCT training indicated a decrease in unsafe behavior exhibited by GCT participants.

Finally, Baker (1998) develops a Maintenance Climate Assessment Survey (MCAS) based upon a model of high reliability organizations in an attempt to capture the maintainers' perspective of risk management, safety climate and culture within the aviation maintenance community. After first developing a survey to capture aviation maintainers' attitudes towards maintenance operations, he then successfully reduced the prototype 67 question survey to a comprehensive 35 question instrument. This 35 question variant of the MCAS is applied in this study to identify trends and possible intervention opportunities in an effort to further reduce human error in aviation maintenance operations within the Navy's Fleet Logistics Support Wing. This study also parallels concurrent research being conducted by Oneto (1999), that concentrates on safety postures across differing aircraft communities within a common Naval Reserve Wing.

B. BACKGROUND

The Fleet Logistic Support Wing (FLSW) is comprised of fourteen squadrons from three very different aircraft communities: the C-9B "Skytrain II," the C-130T "Hercules," and the C-20 "Gulfstream" that cumulatively fly over 62,000 hours a year all over the world. The 27 C-9Bs are the high-speed workhorses of the FLSW with a carrying capacity of 90 passengers or 28,000 pounds of cargo at ranges of up to 2,300 miles. Each of the 20 heavy-lift transport C-130s have a 4,100 mile range and can transport 45,000 pounds of cargo or up to 75 passengers to even the most austere airstrips. Lastly, for high speed/priority deliveries there are 6 C-20s with carrying capacities of 4,500 pounds of cargo or 26 people at ranges of up to 5,200 miles (Peniston,

1998). The U.S. Naval Reserve FLSW is a vital component of the worldwide logistics pipeline that transports Navy and Marine Corps personnel and parts worldwide and resupplies Naval military forces in major supply centers and smaller airfields, alike (Peniston, 1998). Given decreasing budgets, force reductions, reduced spare part inventories and the evolving concept of "precision logistics", a potential Class A FM or any other type or severity of incident within the FLSW could have detrimental effects on forward deployed forces' abilities to fulfill their given missions.

The Commander of the FLSW became aware of the HFMM's recent efforts and requested a systematic assessment of the Wing's maintenance safety posture. The Naval Postgraduate School's School of Aviation Safety became engaged in a number of efforts to assist in this process. Efforts included the Human Factors Analysis and Classification System study of 124 MRMs (Teeters, 1999), GCT briefs at each Squadron location and follow up workshops, maintenance oriented operational risk management training, and the Wing wide administration of the MCAS. Additionally, the results of precious Naval Safety Center on-site maintenance safety surveys were also aggregated. The FLSW initiative was culminated with a maintenance human factors/risk management workshop hosted by the School of Aviation Safety to discuss the results from each effort. The findings were used to determine common/prevalent problem areas, prioritizing them according to severity/probability, and to develop notional intervention strategies.

C. PROBLEM STATEMENT

The Navy's Fleet Logistics Support Wing has an outstanding mishap record with only one Class A mishap in the last 20 years. However, maintenance factors continue to

be a factor in one out of every five Naval Aviation mishaps. This thesis constitutes the final prong of the HFMM's three-pronged approach currently being conducted at the request of the Commander, FLSW. The study utilizes the 35 question variant of the MCAS in order to capture and assess the organizational safety climate of the FLSW's aviation maintenance community based upon the model of high reliability organizations in order to help identify and reduce human error in Naval Aviation. Accordingly, it investigates the following questions:

1. What is the safety climate of the FLSW based upon a model of "high reliability" organizations from the aircraft maintainer's perspective?
2. Are there discernable differences between the three aircraft communities surveyed that comprise the FLSW based upon the "high reliability" organization model?
3. Do the results of the survey match perceptions of actual errors and factors that lead up to them?
4. Can the Maintenance Climate Assessment Survey (MCAS) be improved?

D. SCOPE AND LIMITATIONS

The intent of this study is to gain a better insight into the climate and culture of the maintenance community of the FLSW in order to better develop intervention strategies that would help reduce human error in aviation maintenance. It is hoped that lessons learned through this study can produce procedures and processes that are both directly applicable and beneficial to all of Naval Aviation. For the purpose of this study only Naval Aviation maintenance personnel of the squadrons that comprise the FLSW are

surveyed. This study includes 13 of the 14 FLSW squadrons; the lone squadron not surveyed (VR-51, Kaneoe Bay, HI) utilizes civilian contract maintenance of its aircraft.

The survey was administered on site and in a group setting at the various participating squadrons. Additionally, the survey was given in conjunction with a scheduled maintenance safety presentation on human factors issues in aviation. The squadrons were in various stages of training and operational tasking at the time of the survey being administered. Some Squadrons were in a safety standdown, some were taken during a "drill" weekend while still other Squadrons were in "off-drill" weekend. Lastly, some were executing a normal flight schedule routine while other Squadrons where in a "no fly" status weekend. The varying operational taskings that the Squadrons were simultaneously undertaking during the administration of the MCAS accounted for much of the variance in the number of surveys collected from each Squadron. The potential MCAS respondents were briefed on the survey and its purpose and questions that arose pertaining to the survey were answered by the survey administer. The surveys were then immediately collected upon completion to allow for maximum accountability. For the purpose of this study, two squadron's responses (VR-55 and VR-57) were transformed from the 67 item MCAS utilizing the mapping indicated in Baker's (1998) thesis to the current 35 item MCAS.

Chapter II contains a literature review on investigative scope, accident causation, climate, culture and safety, and high reliability organizations. In chapter III the methodology used in this study is discussed. Chapter IV presents the results of this study. Lastly, chapter V's conclusions include findings and recommendations.

E. DEFINITIONS

This study uses the following definitions (DON, 1989):

Naval Aircraft. Refers to U.S. Navy, Naval Reserve, U.S. Marine Corps, and U.S. Marine Corps Reserve aircraft.

Mishap. A Naval Aviation mishap is an unplanned event or series of events directly involving naval aircraft, which result in $10,000 or greater cumulative damage to naval aircraft or personnel injury.

Mishap Class. Mishap severity classes are based on property damage and personnel injury. The following are the definitions of the three major severity classes:

a. Class A. A mishap in which the total cost of property damage (including all aircraft damage) is at least $1,000,000; or a naval aircraft is destroyed or missing; or any fatality or permanent total disability of a person occurs with direct involvement of naval aircraft.

b. Class B. A mishap in which the total cost of property damage (including all aircraft damage) is between $200,000 and $1,000,000 and/or a permanent partial disability occurs and or five or more personnel are hospitalized.

c. Class C. A mishap in which the total cost of property damage (including all aircraft damage) is between $10,000 and $200,000 and/or injury results in one or more lost workdays.

II. LITERATURE REVIEW

A. OVERVIEW

In April 1996, Vice Admiral Bennitt established the Human Factors Quality Management Board (HFQMB) in order to address the biggest remaining challenge in aviation safety- preventing human error. To aid in matching accident causal factors to appropriate intervention areas the HFQMB is using a model for human error created by the Naval Safety Center (Nutwell & Sherman, 1997). Human Factors Analysis and Classification System (HFACS), an adaptation of Reason's (1990) human error model, is applied to classify Naval aircraft mishaps. Early HFACS analysis identified classic human error forms described by Reason such as slips, lapses, mistakes, and violations. HFACS also identified human errors related to supervisory and aircrew conditions that "set the stage" for active human error forms to occur. (Nutwell & Sherman, 1997). The application of HFACS to Fiscal Years 1990-1996 Class A Naval Aviation FMs indicated that supervisory factors could be identified in over half of the so-called "pilot error" mishaps (Ciavarelli & Figlock, 1998).

Of the three kinds of human activity that are universal in hazardous technologies such as Naval Aviation: control under normal conditions, control under emergency conditions, and maintenance-related activities, Reason (1997) asserts that the latter of the three poses the largest human factors problem. He contends "Errors by pilots, control room operators, and other 'sharp-end' personnel may add the finishing touches to an organizational accident, but it is often latent conditions created by maintenance lapses that either set the accident sequence in motion or thwart its recovery."

The Maintenance Extension (ME) of HFACS as developed by Schmidt, Schmorrow, and Hardee (1998) depicts Supervisory, Maintainer and Working Conditions as latent factors that can impact a maintainer's performance and can contribute to an active failure, an Unsafe Maintainer Act. An unsafe maintainer act may immediately or eventually lead directly to a mishap or injury. Additionally, the unsafe maintainer act may contribute to and become a latent maintenance condition to be consequently dealt with by "sharp end" personnel such as aircrew (see Figure 1). The HFACS ME depicts the impact of organizational climate on maintenance safety.

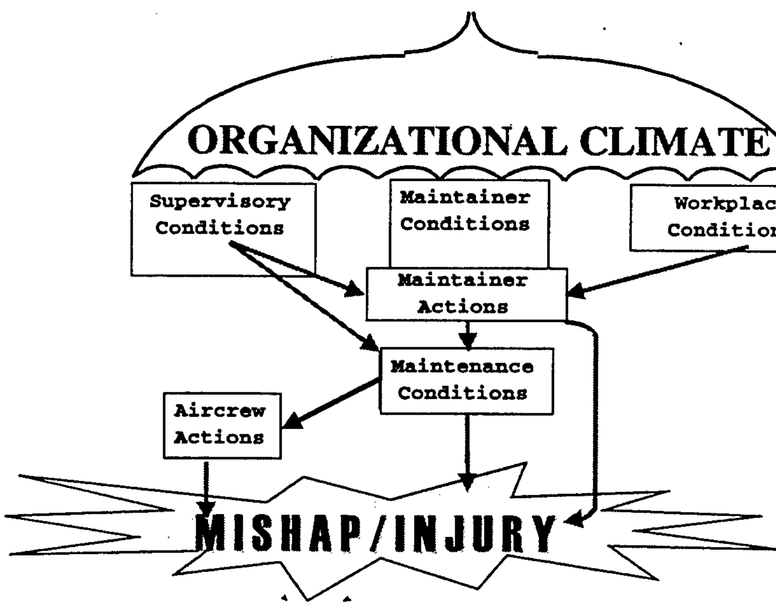

Figure 1. HFACS Maintenance Extension Diagram.

B. INVESTIGATIVE SCOPE

A number of experts within the aviation research community have recently argued that there is now an urgent need to complement analyses of individual human error by

moving towards an understanding of the role played by broader system factors in accidents such as organizational factors. The International Civil Aviation Organization (ICAO) states that:

> The late 70's, 80's, and 90's will undoubtedly be remembered as the golden era of aviation Human Factors. Cockpit (and then Crew) Resource Management (CRM), Line-Oriented Flight Training (LOFT), Human Factors training programs, attitude-development programs and similar efforts have multiplied, and a sustained campaign to increase the awareness of human error in aviation safety has been initiated. But much to the consternation of safety practitioners and the entire aviation community, human error continues to be at the forefront of accident statistics. (p. 1)

The ICAO authors go on to point out how human error is often precipitated by more systematic, background management and organizational factors.

Adams and Payne (1992) further underscore the point that only limited success in reducing pilot-error accident rates will be achieved if the pilot is the only part of the operational problem being fixed. Enders (1992) makes the additional observation that most aviation accidents have several causes and that to seek a single "probable" cause of an event, such as pilot error or maintenance error therefore misses opportunities for learning. He further suggests that causes involving "management or supervisory inattention at all levels" are the most prevalent category, and perhaps contribute as much to accidents as the total numbers of pilot and maintenance errors put together. Johnston (1991) took Enders' one step further in asserting that the need for aircraft accident analysts to adopt a wider investigative reality. For example, for those instances in which individuals are found to have failed to follow Standard Operating Procedures, any conclusion of the type "the accident occurred because X failed to follow procedure Y"

should not simply be the end of the investigation, but rather should always be followed by the more probing question of "and why was this so?" (Johnston, 1991).

In Naval Aviation and elsewhere, human error is one of a long-established list of "causes" used by the press and accident investigators. Reason (1997) argues that human error is a consequence, and not a cause, due to the fact that human errors are shaped and provoked by precedent workplace and organizational factors. He explains only by understanding the context in which an error was provoked can investigators hope to prevent the error's recurrence explains Reason. There are several stages in the development and investigation of an organizational accident (see Figure 2). The triangular shape represents the system producing an organizational accident, and it has three levels: the person (unsafe acts), the workplace (error-provoking conditions), and the organization. The dark upward arrows indicate the direction of causality and the downward arrow indicates the investigative steps (Reason, 1997).

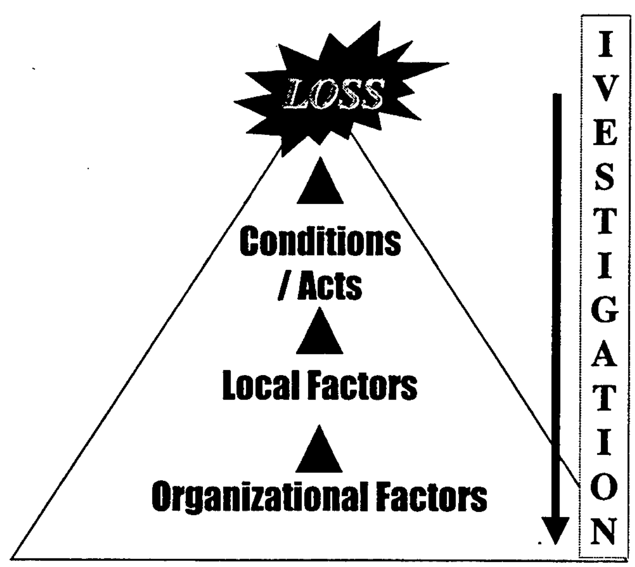

Figure 2. Reason's Stages in Organizational Accident Development/Investigation.

Clearly, one can begin to sense the rising ground swell of researchers and analysts seeking a new way of conceptualizing and quantifying processes of risk handling and management in regards to organizational factors in aviation. HFACS ME is one such tool that is currently being explored to better capture and conceptualize those latent workplace and organizational factors that contribute to human error. A more in-depth understanding of these factors may proactively lead to intervention measures that prevent such accidents from ever occurring.

C. ACCIDENT CAUSATION

Failures in large-scale technological systems such as aviation cannot be described in technical terms alone. Behavioral causes are often predominant in disasters (Pidgeon & O'Leary, 1994). Many of the behavioral causes of disasters can be traced to the social and organizational arrangements of the socio-technical systems associated with the large-scale hazards. Pidgeon and O'Leary (1994) explain that the concept of a socio-technical system stresses the close inter-dependence between a technology and the human resources necessary for its use. These social and technical components interact with, and over time change each other in complex and often unforeseen ways they further explain. It is now clear that the human causes of disasters in complex socio-technical systems cannot all be adequately classified under the catch-all term of "human error" (Pidgeon, 1991). The behavior contributions to disasters are often more subtle and diverse in nature ranging from Reason's (1990) slips, lapses, mistakes and faulty decision making of individuals to more systematic and complex organizational influences.

The first comprehensive analysis of the social and organizational preconditions to disaster in large-scale technological systems is by Turner (1978) in Man-Made Disasters. As a result of detailed analysis of 84 major accidents in the United Kingdom over a ten-year period he concludes that such events rarely come about for any single reason. Turner's (1978) disaster development model focuses in particular upon the information difficulties associated with the attempts of individuals and organizations to deal with uncertain and ill-structured safety problems. He further concludes that prior to any disaster it is typical to find that a number of undesirable events accumulate unnoticed or not fully understood, often over a considerable number of years.

Turner (1978) defines this gradual development of preconditions as the "disaster incubation period." He goes on to state that this period is one in which interacting sets of events build up and are resolved either by taking preventative action to remove one or more of the undesirable events or are concluded by a "triggering event" as a final critical error or a slightly abnormal operating condition. The "trigger event" results in a catastrophe and consequential investigation sheds light on previously unseen background factors. However, caution is warranted in that the immediate trigger may be confused with the more systemic background causes of a disaster, or may even be taken to be the sole cause. Turner states that a further implication of the incubation period is that many incidents are distinguished from full-scale accidents only by the absence of a suitable trigger event, perhaps due to the intervention of chance factors, with the background and latent factors remaining constant. Therefore near-miss incidents can and perhaps must be interpreted as important warning signals.

Perrow (1984) provides a second and related account of failures in socio-technical systems in his book Normal Accidents. Perrow's approach is a more technical one that draws upon his experiences from a perspective of systems engineering. Perrow identifies two general characteristics: complexity (a system can either be complex or linear) and coupling (a system's coupling can be either tight or loose). Systems such as nuclear energy and chemical processing, exhibit both high complexity and tight coupling. These co-occurrences pose particular control difficulties. Such systems have a small tolerance for deviation and, according to Perrow (1984), will be subject almost inevitably to "normal" accidents.

An organization's position within an operational "safety space" is determined by the quality of the processes used to combat its operational hazards explains Reason (1997). There will be some positive correlation between an organization's position within the safety space and the number of incidents that befall it. Organizations that he finds at the resistant end of the space are likely to suffer fewer incidents within a given time frame than those organizations at the vulnerable end. This correlation, however, will never be perfect due to chance. Additionally, Reason (1997) contends that when incident rates occur at a very low level, as in Naval Aviation, the occurrence or non-occurrence of an incident during a given time frame reveals very little about an organization's position within the safety space. Figure 3 shows how hypothetical organizations could be distributed within the safety space at any one time. Reason asserts their positions within the space are determined by their intrinsic resistance or vulnerability to their operating hazards.

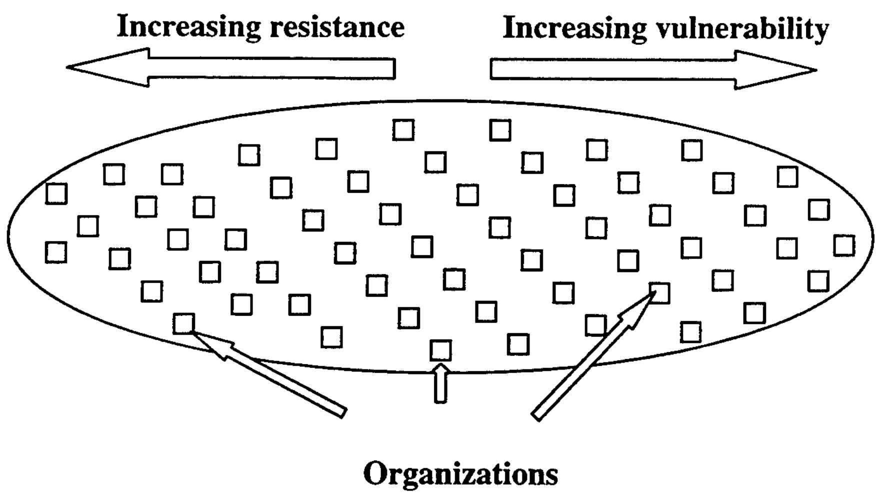

Figure 3. Reason's (1997) "safety space."

D. CLIMATE, CULTURE, AND SAFETY

Organizational climate, by virtue of being a more salient phenomenon of organizational culture, lends itself to direct observation and measurement and thus has had a longer research tradition (Schein, 1990). Zohar (1980) discusses various concepts of safety climate. She considers safety climate to be a subset of an organization's overall climate. Safety climate refers to the shared perception of an organization's members that the organization's leaders are genuinely committed to safety of operations, and have taken appropriate measures to communicate safety principals, and to ensure adherence to safety standards and procedures (Zohar, 1980). Climate is only a surface manifestation of culture suggests Schein (1990), and thus research on climate has not enabled researchers to delve into the deeper causal aspects of how organizations function. Explanations for variations in climate and norms are essential, and it is the need for this illusive information that ultimately drives analysts to "deeper" concepts such as culture (Schein, 1990).

Current interest in the term "safety culture" can be traced directly to the accident at the Chernobyl nuclear plant in the former Soviet Union and the response of the Western nuclear industries to the human and organizational causes of the disaster (Pidgeon, 1991). It is argued that safety culture represents a new way of conceptualizing processes of risk handling and management in organizational and other contexts (Turner, Pidgeon, Blockley, & Toft, 1989). Turner et al. (1989) broadly define safety culture as the set of beliefs, norms, attitudes, roles and social and technical practices within an organization which are concerned with minimizing the exposure of individuals, both within and outside of the organization, to conditions considered to be dangerous. A safety culture is more than a group of individuals enacting a set of safety guidelines; it is a group of individuals guided in their behavior by their joint belief in the importance of safety, and their shared understanding that every member willingly upholds the group's safety norms and will support other members to that common end (Merritt & Helmreich, 1996).

Merritt and Helmreich (1996) explain that culture gives us cues and clues on how to behave in normal and novel situations, thereby making the world less uncertain and unpredictable for us. They further describe two important and distinct components of culture. The surface culture, or outer layer of culture consists of observable behaviors and recognizable physical manifestations such as members' uniforms, signs and logos, and documents. The deep structure, or inner layer of culture, consists of the values, beliefs, and assumptions that underlie the surface structure and provide the logic that guides the members' behaviors (Merritt & Helmreich, 1996).

Schein (1990), in his comprehensive review of organizational culture described how culture is the driving force and the guiding principal behind an organization's goal structure, a means to attaining goals, the source of criteria for measuring progress, and the origination of methods for correcting deviations from norms and expected outcomes. He posits once an organization has evolved into a mature culture because it has had a long and rich history, that culture creates the patterns of perception, thought, and feeling of every new generation in the organization and, therefore, also "causes" the organization to be predisposed to certain kinds of leadership. In that sense the mature group, through its culture, also creates it own leaders. An important paradox of mature culture to understand, explains Schein (1985) is this: leaders create cultures, but cultures, in turn create their next generation of leaders.

Schein (1990) finds culture also molds behavior of individuals through a system of rewards, expectations about status, power, authority, established group boundaries for inclusion or exclusion, and underlying concepts for managing deviations from norms. He adds that culture is learned by individuals who join an organization and is strongly influenced by the organization's structure and leadership. The principal factors that contribute to an organization's culture include operational criteria for personnel selection, formal training practices, explicit and implicit role expectations, and especially the actions of leaders as demonstrated by their example. Schein (1990) believes an organization's culture is heavily influenced by what leaders pay attention to, and by what they express as the core values or expectations of personnel under their supervision.

Pidgeon and O'Leary (1994) view the principal cultural unit within which a safety culture is assumed to be located is the organization. Within the organization, members

will all be selected, trained, and work within a corporate setting that both shapes beliefs and regulates behavior. They feel there is a sense in which it is misleading to talk of an organization or corporate culture per se. Rather, it is possible to think of the culture of small groups of workers or workcenter, of departments, divisions, and organizations being both nested within and sometimes overlapping one another.

E. HIGH RELIABILITY ORGANIZATIONS

Roberts (1988) and Libuser (1994) explain that High-Reliability Organizations (HROs), organizations that operate in a hazardous environment, yet produce very low rate of accidents and incidents, which operate effectively and safely have certain key characteristics in common. Some of those characteristics are leadership style, sound safety management policies, procedure standardization, adequacy of resources and staffing, a defined system for risk management, and other factors. While studying on site the operations of "safe" technologically complex organizations such as the U.S. Navy's nuclear powered aircraft carriers Roberts (1988) argues that existing organizational research is of little help in understanding the organizational processes within such High Reliability Organizations (HROs). She (1988) claims that there are significant differences in the internal processes of organizations as a function of the degree to which their production technologies are perceived as hazardous or the consequences of individual failures vary in severity.

Based upon the earlier research of Roberts, Libuser (1994) developed a Model of Organizational Safety Effectiveness (MOSE) that categorized the traits of HROs into five components: 1) Process Auditing (PA) - an ongoing system to monitor hazards; 2)

Reward System (RS)- expected compensation or disciplinary action used to shape behavior; 3) Quality Assurance (QA)- policies and procedures for promoting quality performance; 4) Risk Management (RM)- organizational risk perception and mitigation; and 5) Command and Control. (CC)-policies and procedures to mitigate risks. Examples of conventional organizations requiring and possessing high reliability today are power plants, chemical manufacturing plants, oil refineries, and transportation industries.

The elements described by Libuser and Roberts map very neatly into Turner (et al., 1989)'s original theoretical account of what might constitute a good safety culture. Those four principal areas Turner et al. propose are: 1) location of responsibility for safety at strategic management level, 2) distributed attitudes of care and concern throughout an organization, 3) appropriate norms and rules for handling hazards, and 4) on-going reflection upon safety practice. Additionally, Degani and Weiner (1994) find there is a need to have alignment between all levels within a safety culture: philosophy (strategic), policy (tactical), procedures (operational), and practices (working). Schein (1985, p. 2) who was emphatic about the primacy of leadership influence on the culture of an organization would argue that the leaders must burden the responsibility of seeing that alignment carried out at all levels: "The *only thing of real importance that leaders do is to create and manage culture* and that the unique talent of leaders is their ability to work with culture."

F. NAVAL AVIATION AS A HIGH RELIABILITY ORGANIZATION

Naval Avaition is one of many organizations that is recognized as a HRO. As part of the HFQMB's drive to reduce human error in aviation mishaps, Ciavarelli and

Figlock (1997) created a survey instrument, the Command Assessment Survery (CAS). Based upon Libuser's MOSE, the survey attempts to capture and assess the HRO aspect of Naval Aviation from an aircrewman's perspective. Based on the analysis of 1,254 aviators who responded to the survey the CAS's results indicate that organizational and supervisory issues are seen by aircrewmen as impacting flight safety (Ciavarelli & Figlock, 1997).

Baker (1998) modified the CAS and developed a prototype 67-item Maintenance Climate Assessment Survey (MCAS) in an attempt to capture and assess safety from the perspective of Naval Aviation aircraft maintainers. With the assistance of some experts in the field of aviation maintenance 67 questions were initially developed from 155 candidate questions that were tailored specifically to aviation maintenance. One additional maintenance specific component was created and added to the existing MOSE: Communication/Functional Relationships. Through principal component analysis Baker finds that his survey data is dominated by one dimension accounting for nearly a third of the data's variance with all six of the MOSE components loading upon the dominant component. Through factor analysis and a number of other regression techniques Baker is then able to successfully reduce the prototype 67 question survey into a comprehensive 35 question instrument. It is the 35 question variant of the MCAS developed by Baker that is applied in this study to further improve the understanding of the possible influences of human factors in aviation maintenance operations within the FLSW.

G. SUMMARY

Latent accident-producing conditions are present now; it is not necessary to wait for bad events to find out what they are argues Reason (1997). Organizations such as Naval Aviation need principal ways of identifying their most urgent process problems in order to deploy limited resources in most efficient and timely manner. The MCAS can be one such tool. Differences identified in safety climate assessments from commonly held perceptions among organizations may prove to be a root source of certain unsafe attitudes and behaviors. The early detection of these differences will undoubtedly become an integral part of a proactive and vital mishap prevention process. To conclude, the question of whether one can effectively measure an organization's safety climate and take corrective action to mend deficient processes prior to the occurrence of a accident, continues to be perhaps the most important issue in risk management today, both for Naval Aviation and other high-reliability organizations.

III. METHODOLOGY

A. RESEARCH APPROACH

The intent of this study is to assess the aviation maintainer's perception on safety and to achieve a better understanding of the climate within the organization in which he/she operates. This study involves the analysis of data obtained from a Maintenance Climate Assessment Survey (MCAS) that is based on an existing model of High-Reliability Organizations (HROs). This is done in order to identify factors that may be utilized in the improvement of safety in aviation maintenance practices. The data analysis in this thesis entails descriptive statistics, principal component analysis, cluster analysis, analysis of variance (ANOVA), and multiple comparisons in ANOVA.

B. DATA COLLECTION

1. Subjects

The subjects used in the data collection are Navy officers and enlisted personnel involved in aviation maintenance of the Fleet Logistic Support Wing (FLSW); no civilians participated in the survey. The survey was administered to 13 of the 14 Squadrons of the FLSW. The lone squadron not surveyed (VR-51, Kaneoe Bay, HI) utilizes civilian contract maintenance of its aircraft; meanwhile, the 13 Squadrons that were surveyed are all maintained by selective reserve and active duty personnel. Additionally, those thirteen squadrons represent three different communities of aircraft: the C-9B "Skytrain II," the C-130T "Hercules," and the C-20 "Gulfstream." The survey respondents are primarily enlisted Navy personnel assigned to aviation maintenance

departments. Listed in Table 1 are the participating Squadrons of the FLWS, their locations and aircraft type.

SQDRN	LOCATION	AIRCRAFT
VR-1	WASHINGTON D.C.	C-20
VR-46	ATLANTA, GA	C-9
VR-48	WASHINGTON D.C.	C-20
VR-52	WILLOW GROVE, PA	C-9
VR-53	WASHINGTON D.C.	C-130
VR-54	NEW ORLEANS, LA	C-130
VR-55	MOFFIT FIELD, CA	C-130
VR-56	NAS NORFOLK, VA	C-9
VR-57	NORTH ISLAND, CA	C-9
VR-58	JACKSONVILLE, FL	C-9
VR-59	FT WORTH, TX	C-9
VR-61	WHIDBEY ISLAND , WA	C-9
VR-62	BRUNSWICK, ME	C-130

Table 1. FLSW Participating Squadrons.

2. Instrument

The Maintenance Climate Assessment Survey (MCAS) developed by Baker (1998), a self-administered, group survey consisting of fifteen demographic and thirty-five maintenance related questions is used. The demographic portion of the survey includes questions that gather responses on variables such as respondent's rank, service, work shift, years of service, and years of maintenance experience. It also includes inquiries into the education level, rating, age, and current maintenance qualifications of the survey participants. Anonymity of respondents are maintained at all times. The 35 maintenance related questions are generated from the five MOSE components of Process Auditing, Reward System, Quality Assurance, Risk Management, Command and Control, and the aviation maintenance specific component of Communication/Functional

Relationships. The survey utilizes a Likert type five point rating scale with verbal anchors as follows: Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree (The 35 item MCAS variant is included in Appendix A).

3. Procedure

The survey is administered on site and in a group setting at the various participating Squadrons. Additionally, the survey is given in conjunction with a scheduled maintenance safety presentation on human factors issues in aviation. The Squadrons are in various stages of training and operational tasking at the time of the survey being administered. Some Squadrons are in a safety standdown, some are taken during a "drill" weekend while still other Squadrons are in "off-drill" weekend. Lastly, some are executing a normal flight schedule routine while other Squadrons are in a "no fly" status weekend. The varying operational taskings that the Squadrons are simultaneously undertaking during the administration of the MCAS account for much of the variance in the number of surveys collected from each Squadron. The potential MCAS respondents are briefed on the survey and its purpose and questions that arise pertaining to the survey are answered by the survey administer. The surveys are then immediately collected upon completion to allow for maximum accountability.

For the purpose of this study, two squadron's responses (VR-55 and VR-57) are transformed from the 67 item MCAS utilizing the mapping indicated in Baker's (1998) thesis to the current 35 item MCAS.

C. DATA ANALYSIS

1. Data Tabulation

Survey data is manually entered into an Excel spreadsheet. The spreadsheet consists of rows of respondents and columns of survey questions (both demographic and MOSE component). Demographic questions record mainly bivariate and multivariate responses. Component question results are coded into the database by assigning scores of 1, 2, 3, 4, or 5 corresponding to the Likert scale of "Strongly Disagree," "Disagree," "Neutral," "Agree," and "Strongly Agree," respectively. If no response was given to the question the word "BLANK" is entered. Two questions (questions 5 and 27) in the 35 item MCAS are negatively anchored. A negatively anchored questions seeks to solicit a response of "Strongly Disagree" or "Disagree" if systems addressed in the question are functioning in a favorable manner. (A response of "Strongly Agree" to a negatively anchored question would raise issues of concern to the subject matter of the question.) For clarity of discussion in the remainder of this study both questions' responses have been transposed to reflect responses as if the questions are positively anchored. All data is then imported into S-Plus 4.5 for further multivariate statistical data analysis.

2. Statistical Analysis

Descriptive non-parametric analysis is conducted on the survey data in order to describe basic and general information about the demographic and question results. Basic summary statistics are developed. Some results include distributions of survey respondents by age, service, education, rank, and current maintenance qualifications. Additionally, frequency of responses, means, and standard deviations are tabulated for the MOSE components, individual questions, and aircraft communities. The S-Plus 4.5

(Mathsoft, 1997) program is used for multivariate statistical analysis. Principal Component and Cluster methodologies such as agglomerative nesting and divisive analysis are used to further validate the stability of the MCAS. Analysis of variance (ANOVA) and multiple comparisons utilizing Tukey's procedure for pairwise comparison are utilized to compare the effects of the three-leveled factor aircraft community and the six-leveled factor MOSE component have on the mean responses of the survey's respondents.

IV. RESULTS

A. DESCRIPTIVE STATISTICS

1. Sample

Nearly 1000 Maintenance Climate Assessment Surveys are collected from military personnel serving in the squadrons that comprise the Fleet Logistics Support Wing. Of these, 819 surveys indicate some amount of aviation maintenance experience on behalf of the respondent. The analysis of these 819 surveys will be addressed in the Results section of this thesis.

2. Demographics

Descriptive statistics are developed for the survey respondents. A demographic breakdown according to respondent's rank was created for each community's aviation maintenance experienced personnel and is presented in Table 2. Approximately 72% of those participating in the MCA Survey are personnel serving in enlisted ranks of E4-E6. This seemingly high percentage makes intuitive sense given that the majority of aviation maintenance performed and immediate supervision provided are from service members of this rank category.

	Respondent Rank Response										
	Blank		E1-E3		E4-E6		E7-E9		Officer		
Community	#	%	#	%	#	%	#	%	#	%	Grand Total
C130	3	1.1%	23	8.5%	195	71.7%	22	8.1%	29	10.7%	272
C20	0	0.0%	4	7.1%	42	75.0%	9	16.1%	1	1.8%	56
C9	6	1.2%	35	7.1%	349	71.1%	67	13.6%	34	6.9%	491
Grand Total	9	1.1%	62	7.6%	586	71.6%	98	12.0%	64	7.8%	819

Table 2. MCAS Respondents' Rank By Frequency of Response and Percentage.

Junior enlisted, senior enlisted and officer numbers appear to be in proper and similar proportion for all communities as well as can be seen in the histogram displayed in Figure 4 below. Notice that the communities with the most/least senior enlisted participants have the least/most officers. This makes sense in that higher level supervision will be provided by either the senior enlisted or officer ranks with an aggregate of approximately 20% of the survey respondents coming from either of these two rank categories. Histograms of other descriptive demographic variables such as: Service Type, Education Level, Rating, Current Maintenance Qualifications, and Age of this study's participants are located in Appendix (B).

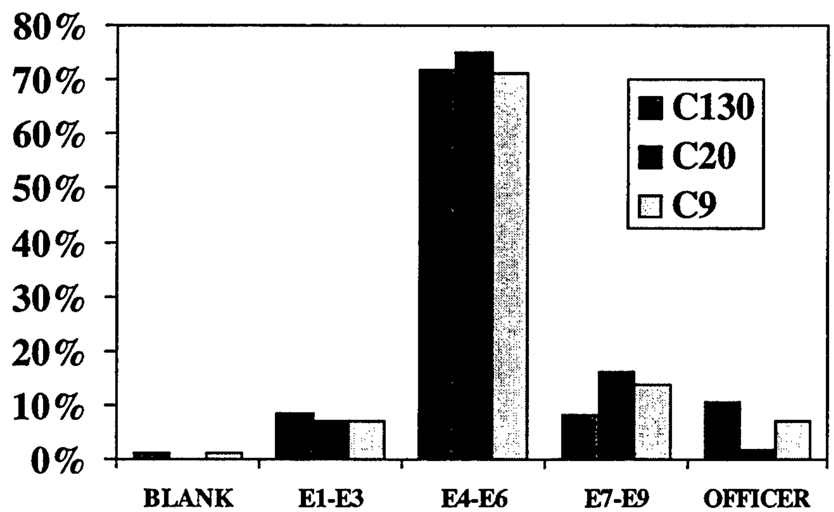

Figure 4. MCAS Respondents' Rank by Percentage.

B. MOSE COMPONENT STATISTICS

Table 3 displays the six MOSE categories and respective MCAS questions that pertain to each component. Summary statistics from evaluating the MOSE categories are displayed in Tables 5 through 12. Each table contains the mean community response for each of the questions pertaining to a particular MOSE component and an overall community MOSE component mean. Standard deviations indicating dispersion from the mean value of each question are computed and are found in Appendix (C). Bar charts of responses may prove insightful in helping visualize the proportion of Likert scale responses (1 = "Strongly Disagree," 2 = "Disagree," 3 = "Neutral/Mixed," 4 = "Agree," 5 = "Strongly Agree") per community per MOSE component and are also found in this section.

MOSE Category	Questions
Process Auditing	1, 2, 6, 8
Reward System	4, 13, 14, 25, 32
Quality Assurance	3, 7, 12, 16, 22, 26, 28, 29, 30
Risk Management	9, 15, 24, 31, 34
Command & Control	11, 17, 18, 19, 23, 35
Communication / Functional Relationships	5, 10, 20, 21, 27, 33

Table 3. MOSE Categories and Questions.

1. Process Auditing

The first MOSE component, Process Auditing (PA), contains four questions:

1.) My command has a dedicated program that targets individual training deficiencies and ensures the uniform enforcement of SOPs among maintenance personnel.

2.) My command monitors maintainer qualifications and support equipment licensing.

6.) My command adequately reviews and updates safety practices, follows established standards and maintains quality control, ensuring that all maintainers are responsible and accountable for safe maintenance.

8.) Medical and safety staff are used to help identify, manage, and temporarily restrict personnel with personal issues and those who pose a risk to safe maintenance in this command.

All questions are positively answered with a mean range from 3.17 to 4.37 across all questions with community means ranging from 3.64 to 3.90 (see Table 4). Additionally, the PA component yields the highest combined component mean of all the six MOSE categories with a mean value of 3.76. Below in Table 5 are the responses and percentages of responses to the PA component questions generated by the aircraft communities that comprise the VR Wing. Additionally, Figure 5 is a histogram of the PA component responses.

	Questions				Component
Community	**1**	**2**	**6**	**8**	**Mean**
C-130	3.50	4.00	3.88	3.17	**3.64**
C-20	3.64	3.96	3.86	3.25	**3.68**
C-9	3.82	4.37	4.10	3.33	**3.90**

Table 4. Process Auditing Component Means.

	Likert Scale Responses										
	1		2		3		4		5		
Community	#	%	#	%	#	%	#	%	#	%	Grand Total
C130	30	2.8%	93	8.7%	261	24.4%	537	50.2%	148	13.8%	1069
C20	8	3.6%	17	7.6%	46	20.5%	121	54.0%	32	14.3%	224
C9	22	1.1%	114	5.9%	374	19.4%	933	48.4%	484	25.1%	1927
Grand Total	60	1.9%	224	7.0%	681	21.1%	1591	49.4%	664	20.6%	3220

Table 5. Process Auditing Component Responses by Frequency and Percentage.

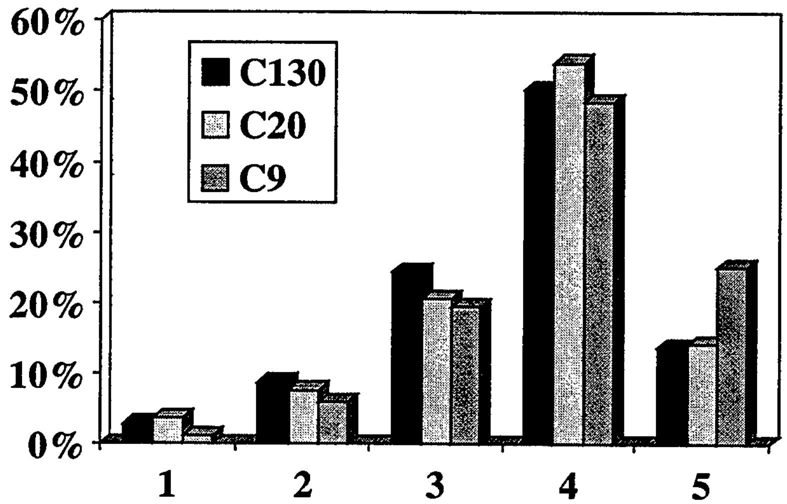

Figure 5. Process Auditing Component Responses.

2. Reward System

The second MOSE component is Reward System (RS) consisting of questions:

4.) Unprofessional behavior is not tolerated in the maintenance department.

13.) Safety concerns or unsafe hazards associated with maintenance/flight line operations can be reported without fear of retribution knowing that the W/C, Q/A, or M/C supervisors will address and manage them for proper corrections.

14.) Violations of SOP, NAMP guidelines or other procedures are discouraged in this command.

25.) Violations of SOP, NAMP guidelines, or other procedures are not common in my command.

32.) Personnel are comfortable telling supervisors about personal problems including illness.

All questions are answered favorably by all communities with mean question responses ranging from 3.37 to 4.13. The C-20 community's overall component mean exceeds 3.80 perhaps indicating that a good reward system is perceived to be in place. The RS component also yields the highest combined component mean (tied with PA) with a mean value of 3.76 (see Table 6). Figure 6 displays the frequency of responses within the RS component.

	Questions					Component
Community	4	13	14	25	32	Mean
C-130	3.75	3.76	3.78	3.52	3.37	**3.64**
C-20	3.77	3.80	4.13	3.71	3.65	**3.81**
C-9	3.96	4.00	3.95	3.56	3.36	**3.77**

Table 6. Reward System Component Means.

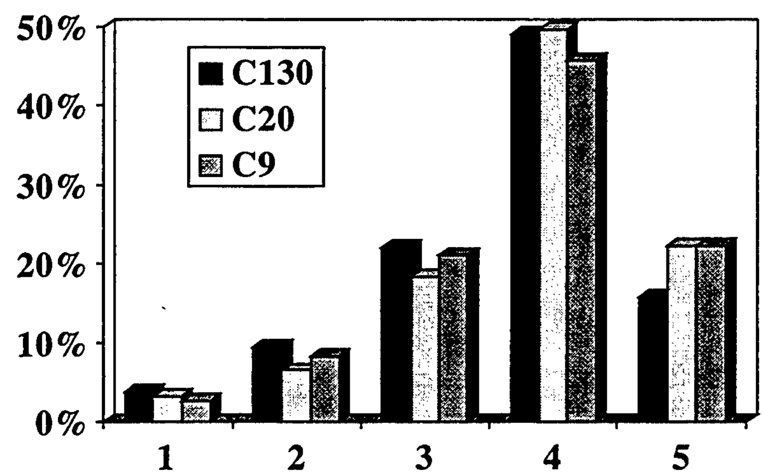

Figure 6. Reward System Component Responses.

3. Quality Assurance

The third MOSE component, Quality Assurance (QA), consists of nine questions. Those questions are:

3.) My command has a reputation for quality maintenance and tool control is taken seriously.

7.) QARs/ CDIs and Maintenance Safety Petty Officer are sought after billets in my command.

12.) Inspectors perform all required actions before sign off.

16.) My supervisors are aware of individual daily workload requirements and recognize safety achievements through rewards and incentives.

22.) Maintainer staffing is sufficient, is equally worked and is equally stressed /fatigued from shift to shift.

26.) Proper tools and equipment are available, serviceable and used and I am provided adequate resources (time, personnel) to accomplish my job.

28.) Required publications are available, current, and used.

29.) The QA division is respected and CDIs / QARs routinely monitor maintenance evolutions ensuring that maintenance gripes are either corrected or addressed prior to flight.

30.) Signing off PQS/JQRs/PARs is taken seriously, not gun decked and maintenance quality is as high on detachments as it is in homeport.

All questions with the exception of question 22 are given favorable responses by all communities. Question 22 earns unfavorable marks from the C-130 and C-20 communities with the C-9 community rating it "neutral". Mean responses from the communities for question 22 range from 2.61 through 3.00. Thus, question 22 identifies an area of mutual concern within the VR Wing that should be further explored for

intervention efforts. Another question of interest is question 3 which yields the highest means for all communities within the QA component ranging from 3.93 to 4.37. Community means for the overall QA component range from 3.51 to 3.73 (see Table 7.). Figure 7 displays the frequency of responses within the QA component.

	Questions									Component
Community	3	7	12	16	22	26	28	29	30	Mean
C-130	4.06	3.32	3.89	3.35	2.61	3.38	3.66	3.84	3.47	3.51
C-20	3.93	3.36	3.91	3.41	2.63	3.39	3.82	3.82	3.68	3.55
C-9	4.37	3.57	4.12	3.53	3.00	3.39	3.77	4.10	3.77	3.73

Table 7. Quality Assurance Component Means.

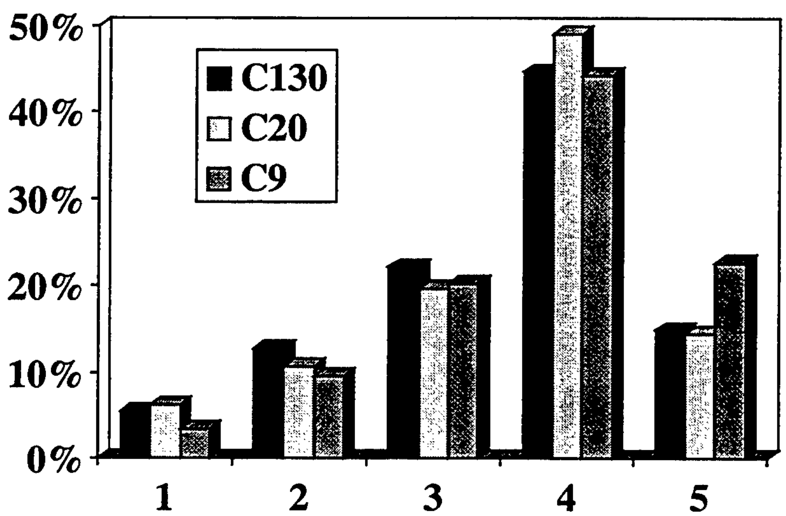

Figure 7. Quality Assurance Component Responses.

4. Risk Management

Table 8 reflects the mean values of responses to the Risk Management (RM) MOSE component, which is comprised of five questions. Those questions are:

9.) Based upon my command's current manning and assets, it is not over-committed.

15.) Supervisors are more concerned with proper aircraft maintenance than mission completion and do not allow cutting corners to meet operational commitments.

24.) Personnel turnover does not affect my command's ability to operate safely.

31.) Safety is an integral part of this command's maintenance planning/flight line operations, where QARs are helpful and the QA division is not "feared."

34.) Maintainers are never purposely put in an unsafe situation to meet the flight schedule.

Two questions are of particular interest and concern in this component. Question 9 is unfavorably responded to by the C-130 community with a mean response of 2.71. Additionally, both the C-9 and C-20 communities respond marginally with means of 3.10 and 3.16 respectively. The relatively low responses to this question across the board are of concern. Perhaps of greater concern is the noticeable difference (approximately 0.4) in the mean response of C-130 community and the other aircraft communities within VR Wing. Question 24 is the other noteworthy question in that both the C-130 and C-9 communities respond unfavorably with mean responses of 2.88 and 2.93 respectively while the C-20 community produces a nearly neutral responses of 3.14. The C-130 community's RM component mean is a meager 3.28 while both the C-20 and C-9 communities' component means are 3.50. Additionally, the RM component yields the second lowest combined component mean of all the six MOSE categories that comprise this survey with a mean value of 3.43. Figure 8 displays the frequency of responses within the RM component.

	Questions					Component
Community	9	15	24	31	34	Mean
C-130	2.71	3.56	2.88	3.79	3.45	**3.28**
C-20	3.16	3.63	3.14	3.89	3.67	**3.50**
C-9	3.10	3.80	2.93	3.86	3.83	**3.50**

Table 8. Risk Management Component Means.

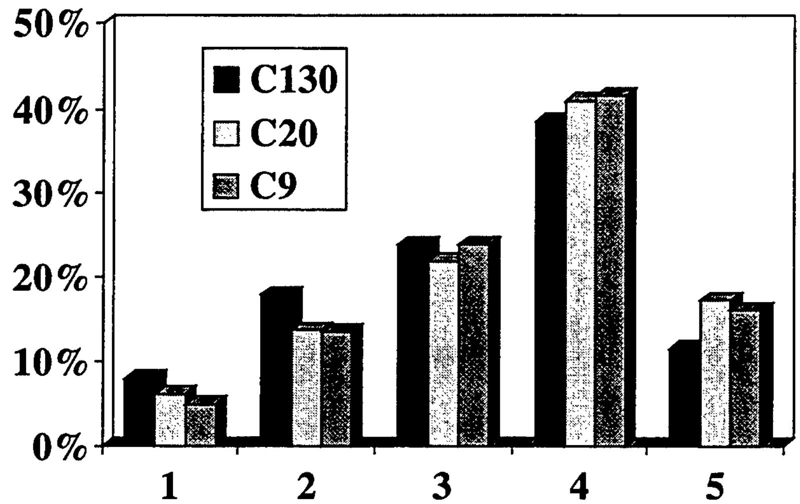

Figure 8. Risk Management Component Responses.

5. Command & Control

The fifth MOSE component, Command & Control (CC), is made up of six questions. Those questions are:

11.) Maintenance control is effective in managing all maintenance activities, coordinating between M/C, W/C, and QA prior to the incorporations of TDs.

17.) Supervisors communicate command safety goals programs and procedures.

18.) W/C supervisors are respected by the maintenance chief/officer.

19.) Qualified personnel properly supervise all maintenance evolutions and maintainers are briefed on the potential hazards associated with maintenance activities.

23.) Multiple job assignments and collateral do not adversely affect maintenance.

35.) Safety education and training in my command are comprehensive and effective and the safety department is respected by the supervisors and maintainers.

The mean responses to the questions range from 2.74 to 3.91 as can be seen in Table 9. The C-20 community's mean of 2.96 to question 18 is unfavorable while the respective C-130 and C-9 community responses of 3.30 and 3.67 are modestly positive in nature. The noticeable and sizeable differences in responses among the three communities may suggest the presence of differing cultural attitudes within the maintenance communities. Another question of significant interest is question 23. Both the C-130 and C-9 communities respond unfavorably with mean values of 2.74 and 2.75 respectively while the C-20 community records a mean response of 3.14. The relatively low rating given by all communities indicates a need to address the perceived adverse effects on maintenance by exploring intervention strategies to help mitigate those effects. Figure 9 displays the frequency of responses within the CC component.

	Questions						Component
Community	11	17	18	19	23	35	Mean
C-130	3.46	3.68	3.30	3.57	2.74	3.63	3.40
C-20	3.34	3.61	2.96	3.48	3.14	3.60	3.36
C-9	3.74	3.89	3.67	3.75	2.75	3.91	3.62

Table 9. Command & Control Component Means.

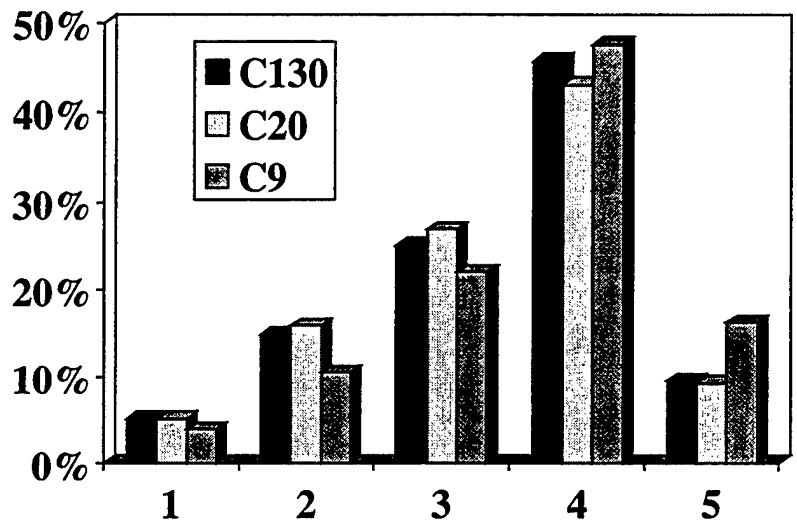

Figure 9. Command & Control Component Responses.

6. Communication/Functional Relationships

Table 10 displays the last MOSE component, Communication/Functional Relationships (CF), which is comprised of six questions:

5.) My command has no problem with passdown between shifts. (Positively anchored)

10.) Within my unit, good communication flow exists up and down the chain of command.

20.) My supervisor shields me from outside pressures which may affect my work.

21.) QARs are never pressured by the maintenance supervisors to sign off a gripe.

27.) Maintenance Control always troubleshoots aircraft discrepancies. (Positively anchored)

33.) I feel I get all information (internal and external) required to perform my job safely, and feel free to report safety violations, unsafe performance or other unsafe behavior.

Question 5, yielded an unfavorable response of 2.63 from the C-20 community while both the C-130 and C-9 communities produced mean values of 3.05 and 3.23. Question 10 is also unfavorably scored by the C-20 community with a response mean of 2.61. (Note: One squadron of the C-20 community recorded very unfavorable mean values for questions 5 and 10 that not only drove the community means lower but more importantly flagged these issues for immediate intervention steps within that particular squadron.) Question 20, although not unfavorably responded to, yielded only slightly better than neutral ratings across the board. Question 27 is of interest because the C-9 community's response of 3.01 is well below the other communities' mean responses of 3.45 (C-130) and 3.64 (C-20). The CF component yields the lowest combined component mean of all the six MOSE categories with a mean value of 3.27 and thus issues contained in this component would serve as a good starting point for mitigating risk in aviation maintenance operations within the VR Wing. Figure 10 displays the frequency of responses within the CF component.

	Questions						Component
Community	5	10	20	21	27	33	Mean
C-130	3.05	3.01	3.00	3.10	3.45	3.69	**3.22**
C-20	2.63	2.61	3.13	3.38	3.64	3.73	**3.18**
C-9	3.23	3.49	3.29	3.40	3.01	3.97	**3.40**

Table 10. Communications/Functional Relationships Component Means.

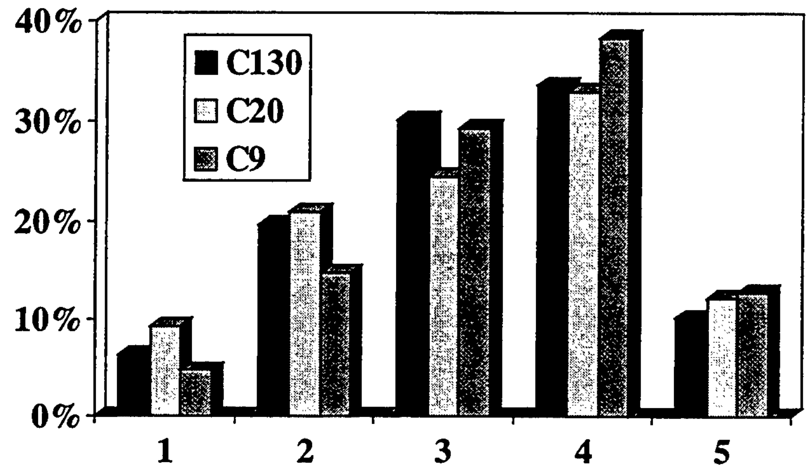

Figure 10. Communication/Functional Relationships Component Responses.

7. MOSE Summary

Some generalized observations can be made in analyzing the MOSE component mean responses. The two MOSE components of greatest concern as identified by aviation maintenance personnel of the FLSW while participating in the MCAS are CF and RM. The focusing intervention efforts in those two areas should be a priority. Almost across the board the C-9 community's mean responses to questions are noticeably higher than those of both the C-130 and C-20 communities. Additionally, the culture of the C-130 maintenance community is very sensitive to questions that pertain to issues of being over-committed, under-manned/under-staffed, burdening disproportionate

workloads, the eroding effects of personnel turnover, and the negative impact of collateral duties acting upon maintenance safety. The old adage of accomplishing more with less seems to have worn thin within the C-130 maintenance community. Lastly, the C-20 maintenance community seems to express concern with coordination, functional relationships, and communication related issues.

C. PRINCIPAL COMPONENT ANALYSIS

Principal Component Analysis (Hamilton, 1992) is performed on the data in an attempt to identify a small set of factors that account for most of the variability of the data. Utilizing S-PLUS 4.5, the command "princomp (X, na.action=na.omit, cor = F)" is used in this analysis. "X" is a 819 by 35 matrix of survey responses. The code "na.action = na.omit" is required in order for S-PLUS to handle cases with missing observations. S-PLUS omits all cases with missing values (coded NA) and does not use them in the performance of a principal component analysis. Ninety such cases are present and thus discarded from the original data due to responses missing in the 35 maintenance related questions that comprised the second part of the survey. This reduces the number of cases to be evaluated in the principal component analysis to 729. The "cor = F" implies that the analysis is based on a covariance matrix rather than a correlation matrix. The covariance matrix is chosen since the original observations are all on a common scale. A scree-plot displays the output of the principal component analysis (see Figure 11). This figure displays each component's contribution to the total variance. Above each bar in the plot is the cumulative percentage of variance accounted for as successive components are added. Notice that nearly one-third of the data's variance is

accounted for by the first component alone with the next nine components' diminishing contributions accounting for only another third of total variance. This suggests that the survey data is dominated by the first component dimension.

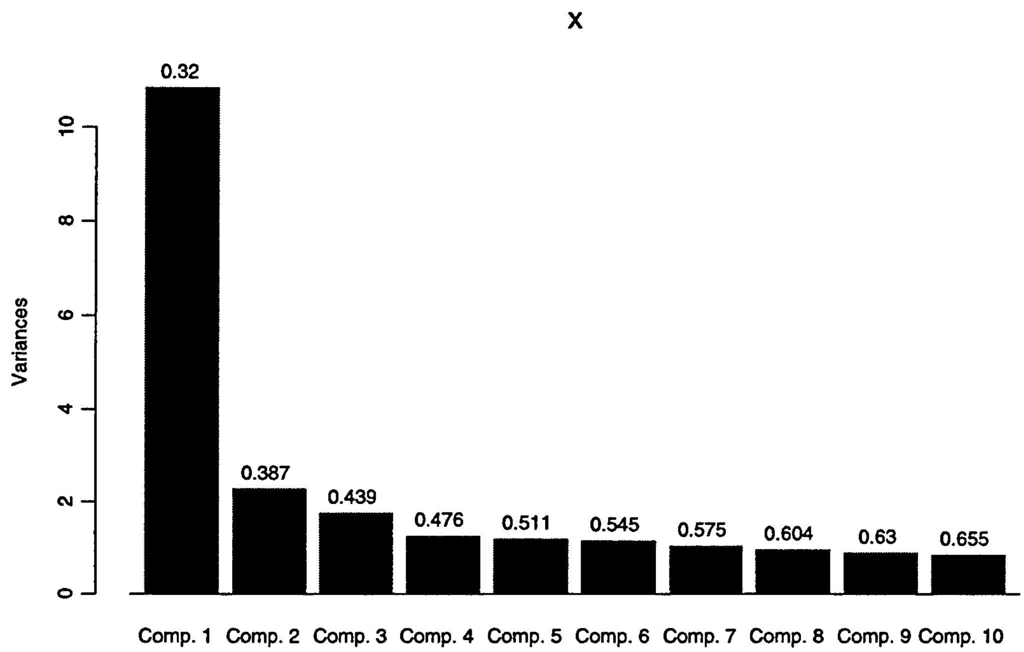

Figure 11. Principal Component Scree-Plot.

The principal component loadings are the coefficients of the principal components transformation. They provide a convenient summary of the influence of the original variables on the principal components (S-Plus 4, 1997). A plot of the variables that load on the first five components is generated by utilizing the following S-PLUS code: "plot(*name*$loadings)," where "*name*" is any name assigned to the principal component object. The dollar sign operator ($) attaches the "loadings" property of the principal component object for plotting. Figure 12 displays the first five components and the variables (survey questions) that load upon each. (Note: a large coefficient (in absolute

value) corresponds to a high loading, while a coefficient near zero indicates the variable has a low loading on the component.)

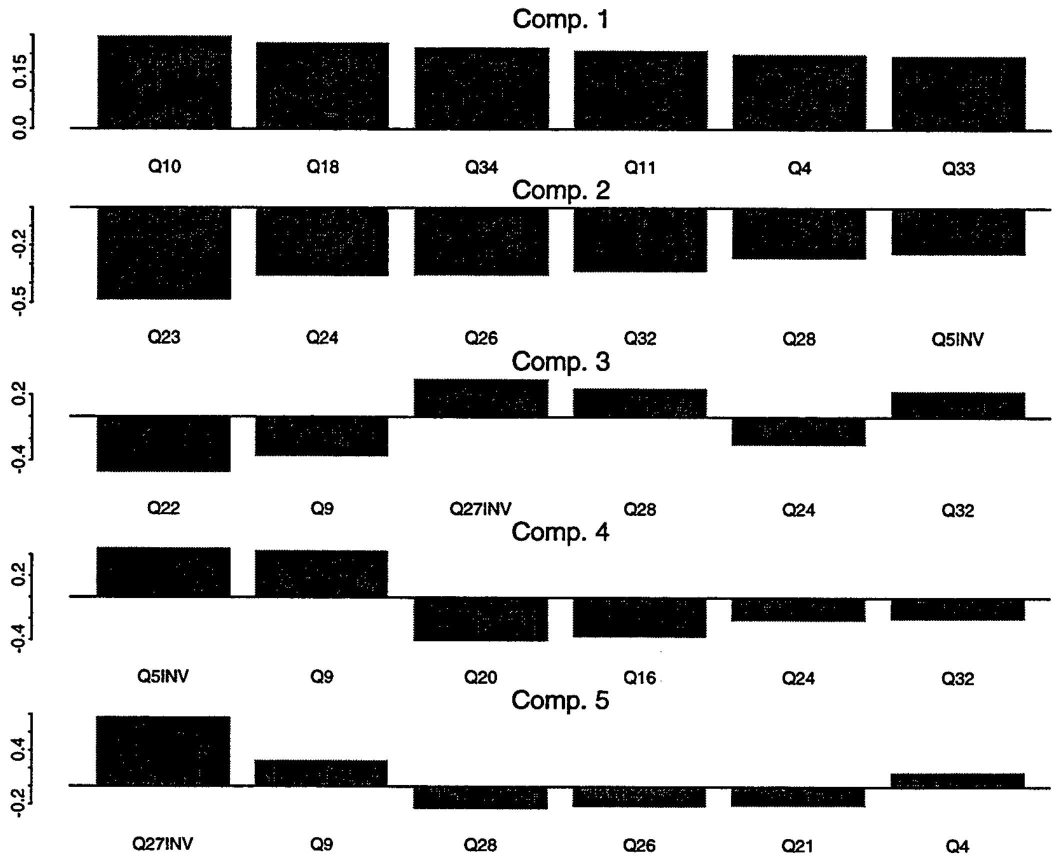

Figure 12. Principal Component Loadings.

Identifying the six questions that load most heavily upon the most dominant component, Component 1, reveals that four of the six MOSE components are represented (CF, RM, CC, and RS). By further looking at a printout of the principal component loadings it is evident that numerous questions load quite heavily on this orthogonal projection with only small perturbations in their values (as perhaps can be inferred by the figure above). The next four components all load across at least three MOSE components

with Components 3 through 5 loading on the QA, CF, and RM questions in particular. Thus, it cannot be said that just any one or two MOSE components contribute to the majority of the variance within the survey but rather that all six MOSE components play an integral in capturing aviation maintainers' attitude with respect to safety.

D. CLUSTERING ANALYSIS

Clustering analysis is a way of classifying a data set into groups that are cohesive but separate (S-Plus 4, 1997). For this study, clustering analysis is performed on the 35 maintenance-related questions comprising the second portion of survey in order to look for trends in how the data is grouping. Two methods by which this can be achieved are agglomerative and divisive hierarchical clustering. Though the two methods attempt to achieve the same end state, the partitioning of the data into separate groups, their respective algorithms operate in polar-opposite fashion.

1. Agglomerative Nesting ("agnes")

A hierarchical agglomerative algorithm constructs a hierarchy of clusterings. Considered a "bottom-up" approach, the S-PLUS agglomerative nesting algorithm is called "agnes." At first, each observation (survey question) is a small cluster by itself. "Agnes" then yields a sequence of clusterings whereas the two "nearest" clusters are combined to form one larger cluster until only one large cluster containing all observations remains. The S-PLUS code used for this study is as follows: "agnes (daisy (t (X)), diss= T)". The data set is transposed through the code "t (X)" so as to cluster across the 35 survey questions, vice the cases. The S-PLUS function "daisy" then computes a dissimilarity matrix for the transposed data matrix "X." The "diss=T"

parameter implies that a dissimilarity matrix will be used in the algorithm's computation of the distance function. The output of the "agnes" function is displayed in a clustering tree diagram with the leaf nodes of the tree being the survey questions. The vertical coordinate of where two branches join on the clustering tree equates to the dissimilarity between combining clusters. The command "plot (*name*)" is used to obtain the clustering tree, where "*name*" is any name assigned to the "agnes" created object. An "agnes" clustering tree created on the survey data is shown in Figure 13.

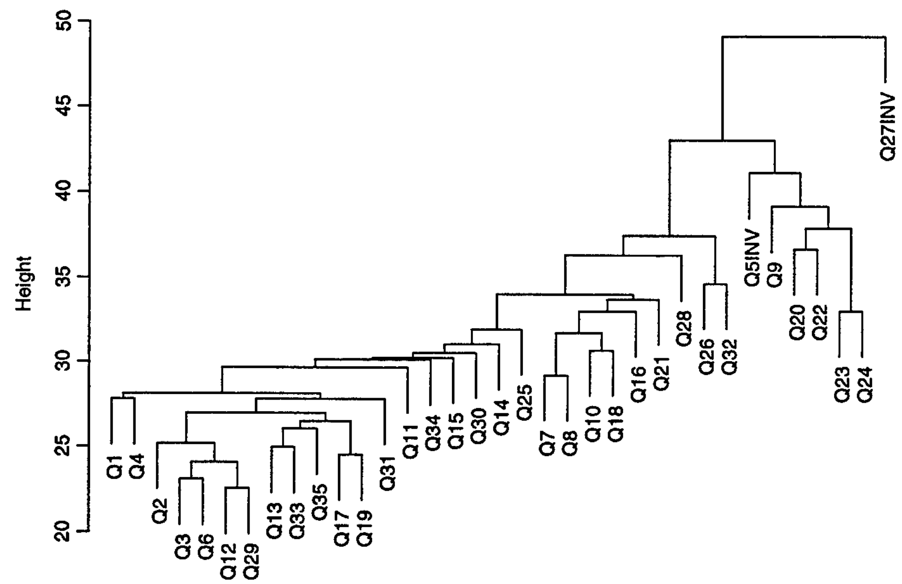

Figure 13. "agnes" Clustering Tree.

Additionally, "agnes" outputs an Agglomerative Coefficient (AC). An AC measures the amount of clustering structure of the data set. An AC of one (1) would indicate a perfect clustering structure and a zero (0) would indicate no clustering

structure. The resulting AC produced from performing "agnes" on the data set is 0.38 indicating a modest clustering structure within the data set.

2. Divisive Analysis ("diana")

A divisive hierarchical algorithm also constructs a hierarchy of clusterings. Considered a "top-down" approach, it begins with one large cluster containing all observations and divides until each remaining cluster contains only a single observation. Clusters with the largest dissimilarity between any two of its observations are selected to split first. To divide a selected cluster, the most disparate item in the group (i.e., the one with the highest average dissimilarity to all other observations in the selected cluster) initiates a "splinter group" (Kaufman & Rousseeuw, 1990). Then for each item outside the splinter group, average distances are computed to all other items and to the splinter group. Items that are closer to the splinter group than any other item are added, otherwise it is paired with whichever item it was closest to. The process is repeated until each cluster contains only a single item.

The S-PLUS code used to perform the divisive analysis on the data set was "diana (daisy (t (X)), diss= T)." The data set is transposed through the code "t (X)" so as to cluster across the survey questions, vice the cases. The S-PLUS function "daisy" then computes a dissimilarity matrix for the transposed data matrix "X." The "diss=T" parameter implies that a dissimilarity matrix will be used in the algorithm's computation of the distance function. The output of the "diana" function is displayed again in a clustering tree diagram. The command "plot (*name*)" is used to obtain the clustering tree, where "*name*" is any name assigned to the object. A "diana" clustering tree created on the survey data is shown in Figure 14. (Note: Likert scale responses to both questions 5

and 27 were inverted so that all questions considered during the clustering analysis were positively anchored.) The resulting divisive coefficient produced from performing "diana" on the data set is 0.46. This is a bit larger than the agglomerative coefficient of 0.38 produced by "agnes".

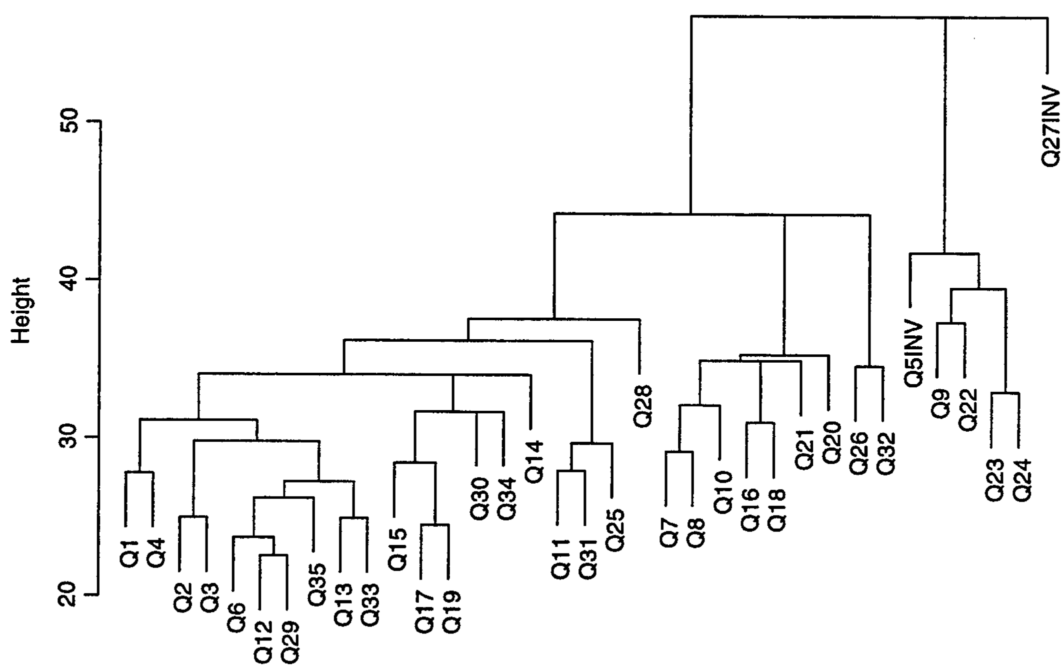

Figure 14. "diana" Clustering Tree.

A visual comparison of both "agnes" and "diana" clustering trees reveals very similar clustering results. Though there is no distinct clustering by MOSE categories, the items do group similarly when both agglomerative and divisive hierarchical clustering is

performed on the MCAS data set. This similar grouping of the survey questions coupled with the modest agglomerative and divisive coefficients does support a clustering structure and further advocates the stability of the survey.

E. ANALYSIS OF VARIANCE

A two-factor analysis of variance (ANOVA) is run to determine if either the aircraft community factor or the MOSE component factor pose any effect on the mean survey response. Let the letter "I" denote the number of levels of the first factor of interest (factor "A" or community) and "J" denote the number of levels of the second factor of interest (factor "B" or MOSE component). With $I = 3$ (the three aircraft communities) and $J=6$ (the six MOSE components), there are then $I*J = 18$ possible cross classifications consisting of a level of factor "A" and a level of factor "B". Each such combination is viewed as a treatment and is denoted by K_{ij}. There is only one result for each possible K_{ij} and the analysis utilizes a two-factor ANOVA with one observation per cell. The factors, levels, and responses are shown in Table 11.

	PA	RS	QA	RM	CC	CF
C-130	3.64	3.64	3.51	3.28	3.40	3.22
C-20	3.68	3.81	3.55	3.50	3.36	3.18
C-9	3.90	3.77	3.73	3.50	3.62	3.40

Table 11. Community Mean Responses per MOSE Component.

There are two hypotheses of interest in a two-factor ANOVA. The first null hypothesis, H_{0A}, states that the different levels of factor "A" have no effect on the true

average response. Likewise, the second null hypothesis, H_{0B}, states that there is no effect from factor "B" on the true average response.

The information in Table 13 is then imported from an Excel spreadsheet into S-PLUS 4.5. The S-PLUS code for conducting the ANOVA is "anova (aov (Avg ~ factor A + factor B, data = X)), where "aov" applies the ANOVA function. The "anova" at the beginning of the code provides degrees of freedom, sum of squares, and mean square values as well as the F-test statistics and corresponding P-values for the ANOVA output. The mean responses listed in Table 13 correspond to the "Avg" parameter which is modeled by each aircraft community and MOSE component ("factor A" and "factor B" respectively). The "X" is the data frame that contains all the information. The information output obtained from running the two-factor ANOVA is displayed below:

```
Analysis of Variance Table
Response: Avg
Terms added sequentially (first to last)
          Df Sum of Sq Mean Sq   F Value  Pr(F)
Comm       2 0.1361446 0.0680723 13.31454 0.001516595
Comp       5 0.5328003 0.1065601 20.84252 0.000053879
Residuals 10 0.0511263 0.0051126
```

With an alpha level of 0.05, the P-value for the community factor variable proves significant at 0.001517. This results in a rejection of H_{0A} in favor of the alternate hypothesis, which states that the communities show real difference with respect to their mean responses to the survey's MOSE components. The MOSE components also prove to be highly significant at 0.000054. This causes us to reject H_{0B} in favor of the claim that the different MOSE components do not all yield the same mean responses.

F. MULTIPLE ANOVA COMPARISONS

Since both factors in the two-factor ANOVA reject the null hypotheses it would be interesting to find out which of the levels of the several factors are significantly different from one another. A multiple comparison procedure such as Tukey's Procedure (or the "T" method) will do just that. Utilizing the Studentized range probability distribution, confidence intervals for all pairwise comparisons are computed at a selected alpha level. In the first case, a pairwise comparison of the three aircraft communities' mean responses will be conducted. The resulting confidence intervals represent the true values of all differences μ_i - μ_j between true treatment means. Each interval that doesn't include the value of zero yields the conclusion that μ_i and μ_j differ significantly at level a level of alpha.

The S-PLUS code for conducting the multiple comparison procedure is "multicomp (A, focus = "factor", method = "tukey", plot = T)." "multicomp" is the call to the S-PLUS function that performs the multiple comparison test. "A" is the object output of the ANOVA run in the previous section on the information from Table #. The code "focus = factor" specifies which of the factors to plot (in this case, the aircraft communities). Various methods are available in the computation of the comparisons, but the "method = "tukey"" code explicitly utilizes the Tukey method. The function provides the standard default alpha level of .05. The "plot = T" code automatically prints the confidence intervals to the graphics device and are displayed in Figure 15.

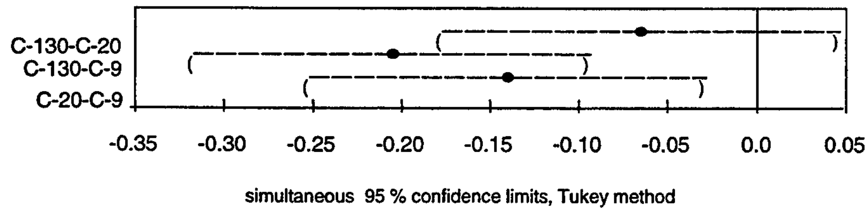

Figure 15. Tukey's Pairwise Comparison of Aircraft Communities.

The S-PLUS code "tapply (X [,"response"], X [,"factor"], mean))" is used to generate a matrix by applying the "mean" function to the "response" variable (the mean responses listed in Table #) over the "factor" levels (the aircraft communities) from the data frame "X." Having the aircraft community means of 3.45 (C-130), 3.51 (C-20) and 3.65 (C-9) arranged in increasing order, the graphical display of the confidence intervals (Figure 15) is used to obtain those pairings that contain the value of zero. Those components were then underlined as shown in Figure 16. Any pair of aircraft communities not underscored by the same line corresponds to a pair of true treatment means that are significantly different. Items within the same grouping do not differ significantly. Thus, Figure 16 shows that there is statistically proven difference in mean responses between the C-9 community and both the C-130 and C-20 communities at an alpha level of .05.

C-130 C-20 C-9

Figure 16. Identifying Community Means That Are Statistically Different.

Now a multiple comparison procedure is run on the other significant factor, MOSE components, and its graphical output is displayed below in Figure 17. Once again the mean value responses are sorted in ascending order and displayed in Table 12. Having the MOSE component mean values arranged in order, the graphical display of the confidence intervals (Figure 11) is used to obtain those pairings that contain the value of zero. Those components were then underlined as shown in Figure 18. Any pair of MOSE components not underscored by the same line corresponds to a pair of true treatment means that are significantly different whereas items within the same grouping are found not to differ significantly. Figure 18 shows that CF is found to be significantly different from all other components other than RM. RM, however, is only significantly different from PA and RS. Lastly, CC is statistically different than both CF and RS components.

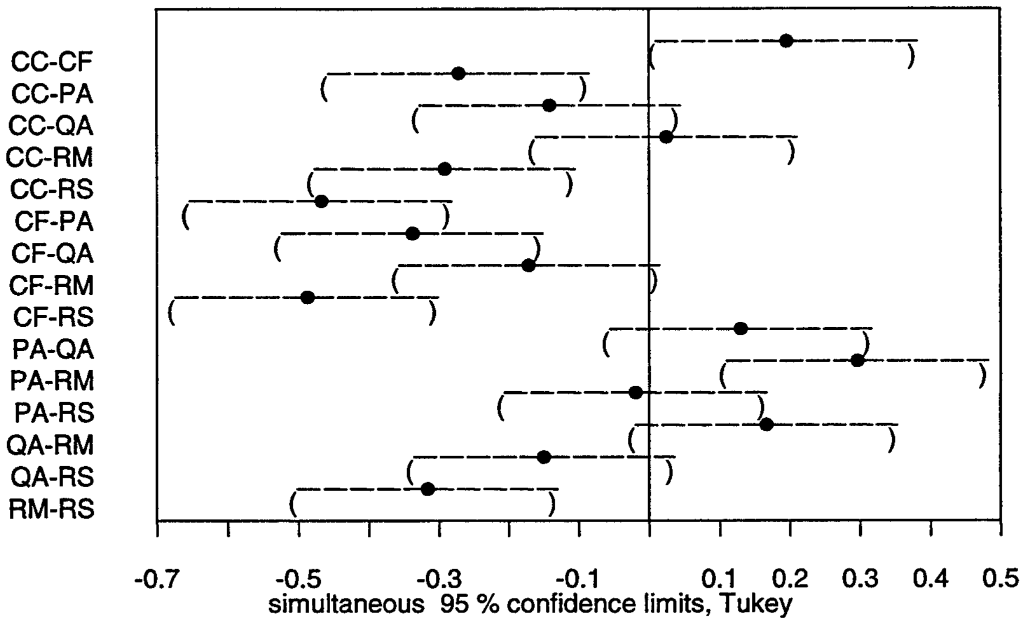

Figure 17. Tukey's Pairwise MOSE Component Comparisons.

CF	RM	CC	QA	PA	RS
3.27	3.43	3.46	3.60	3.74	3.74

Table 12. MOSE Component Means.

CF RM CC QA PA RS

Figure 18. Identifying Statistically Different MOSE Components.

V. CONCLUSIONS

A. FINDINGS

The results of this study conclude that the MCAS can be utilized as a tool for effectively capturing an aviation maintainer's perceptions of safety in maintenance operations. Through analysis of the responses a number of different questions are identified as raising concern within the different communities. Those questions that yielded unfavorable responses or an uncharacteristically low response (question 27 for the C-9 community) are recorded in Table 13 along with their respective MOSE component. Discussions of the individual questions are included in the MOSE Component Analysis section of Chapter IV. Overall, the general safety climate of the FLSW is good; however, some potential areas within each community have been identified for focusing and prioritizing safety intervention efforts.

	Questions								
	CF	RM	CF	CC	CF	QA	CC	RM	CF
Community	5	9	10	18	20	22	23	24	27
C-130	3.05	2.71	3.01	3.30	3.00	2.61	2.74	2.88	3.45
C-20	2.63	3.16	2.61	2.96	3.13	2.63	3.14	3.14	3.64
C-9	3.23	3.10	3.49	3.67	3.29	3.00	2.75	2.93	3.01

Table 13. Potential Intervention Areas Identified by MCAS.

Through Analysis of Variance (ANOVA) and Multiple Comparison testing it is shown that the mean responses of the C-9 community are statistically different than mean responses of both the C-130 and C-20 aircraft communities that comprise the FLSW based upon a model of high reliability organizations. Some generalized observations can be made in analyzing the MOSE component mean responses. Almost across the board

the C-9 community's mean responses to questions are noticeably higher than those of both the C-130 and C-20 communities. Moreover, the culture of the C-130 maintenance community is very sensitive to questions that pertain to issues of being over-committed, under-manned/under-staffed, burdening disproportionate workloads, the eroding effects of personnel turnover, and the negative impact of collateral duties acting upon maintenance safety. The old adage of accomplishing more with less seems to have worn thin within the C-130 maintenance community. Additionally, the C-20 maintenance community seems to express concern with coordination, functional relationships, and communication related issues. Lastly, statistical significance is found along the MOSE components which may also assist in helping to prioritize intervention efforts within the FLSW. The components of Cummunication/Functional Relationships and Risk Management pose the most immediate concern to the aviation maintainers within the FLSW and thus would serve as a good starting point for mitigating risk in aviation maintenance operations.

During the exploratory phase of this study, a few questions were identified for restructuring. This was due in part to a poor fusing of questions during the transition from the prototype 67 question survey to the 35 question survey utilized in this study. A proposed list of revised MCAS questions has been produced with input from the School of Aviation Safety, AIRPAC's Maintenance Training Team, and the Naval Safety Center and is included in Appendix E.

B. RECOMMENDATIONS

This study can be used as a starting point for several different follow on studies. Ideally, MCAS should now be incorporated within Naval Aviation's regular active duty Wings for timely identification and prioritization of potential safety intervention areas within aviation maintenance. Minor modifications of the MCAS could also be made for a Marine Corps specific version of MCAS. Further analysis and comparisons could then be made among similar aircraft communities that are inherent in both the Navy and Marine Corps. Additionally, Marine Corps Reserve aviation units could then be contrasted with this study of the Navy's FLSW. Lastly, a more in-depth study of recent Mishap Data Analysis and MCAS results would be interesting to determine to what degree there is correlation in perceptions of maintenance safety and actual safety records.

APPENDIX A. 35-ITEM MCAS QUESTIONNAIRE

Purpose: The purpose of this survey is to try and gain valuable insight into the maintenance community's perception concerning aviation mishaps within the Navy and Marine Corps. Your participation and answers will be used as a guide in the Navy's on-going efforts to lower the aviation mishap rate.

The first fifteen questions, part I, regard biographical data; information particular to yourself. This information will aid in the analysis of your responses. NO attempts will be made to identify individual respondents or their organizations.

Part II has 35 questions pertaining to the maintenance community. Please respond to the questions with the answer that most correctly reflects your honest opinion. Using a #2 pencil, completely darken each response.

Thank you in advance for your participation!

PLEASE RESPOND TO EACH ITEM.

1. Your rank? ( ) E-1 - E-3 ( )E-4 - E-6 ( )CPO E-7 + ( )Officer

2. Your community?

VFA	( )	HS	( )	VMFA	( )	VF	( )	HSL	( )
VMA	( )	HC	( )	VP	( )	HCS	( )	VX	( )
VR	( )	VQ	( )	VAQ	( )	VAW	( )		

3. Your designator? (LDO, 152X, etc)? __________ / NEC __________

4. Are you currently a department head? ( ) Yes ( ) No

5. Your service? ( ) USN ( ) USNR TAR ( ) SELRES ( ) Other

6. Your shift? ( ) DX ( ) NX ( ) MidX ( ) Other_______

7. Total years of service? _________

8. Total years of Aviation Maintenance experience? ________

9. A-School graduate? ( ) Yes ( ) No ( ) N/A

10. Education level:( ) GED ( ) High School ( )College, #yrs___

11. Unit home location? ( )East coast ( )West Coast ( )Other

12. Your rating? ( )AD/AM ( ) AE/AT ( )PR/AME ( )AO ( )Other

13. Your age? ( ) 17-20 ( ) 21-25 ( ) 25-30 ( ) 30+

14. Current maintenance qualifications?
    ( )Safe for Flight ( )QAR
    ( ) CDI ( )Supervisor
    ( )SPO ( )N /A

15. Duty: ( ) Shore ( ) Sea

Part II	Strongly Agree	Agree	Neutral/ Mixed	Disagree	Strongly Disagree
1. My command has a dedicated program that targets individual training deficiencies and ensures the uniform enforcement of SOPs among maintenance personnel.	( )	( )	( )	( )	( )
2. My command monitors maintainer qualifications and support equipment licensing.	( )	( )	( )	( )	( )
3. My command has a reputation for quality maintenance and tool control is taken seriously.	( )	( )	( )	( )	( )
4. Unprofessional behavior is not tolerated in the maintenance department.	( )	( )	( )	( )	( )
5. My command has a problem with passdown between shifts.	( )	( )	( )	( )	( )
6. My command adequately reviews and updates safety practices, follows established standards and maintains quality control, ensuring that all maintainers are responsible and accountable for safe maintenance.	( )	( )	( )	( )	( )
7. QARs/ CDIs and Maintenance Safety Petty Officer are sought after billets in my command.	( )	( )	( )	( )	( )
8 . Medical and safety staff are used to help identify, manage, and temporarily restrict personnel with personal issues and those who pose a risk to safe maintenance in this command.	( )	( )	( )	( )	( )
9. Based upon my command's current manning and assets, it is not over-committed.	( )	( )	( )	( )	( )
10. Within my unit, good communication flow exists up and down the chain of command.	( )	( )	( )	( )	( )
11. Maintenance control is effective in managing all maintenance activities, coordinating between M/C, W/C, and QA prior to the incorporations of TDs.	( )	( )	( )	( )	( )
12. Inspectors perform all required actions before sign off.	( )	( )	( )	( )	( )
13. Safety concerns or unsafe hazards associated with maintenance/flight line operations can be reported without fear of retribution knowing that the W/C, Q/A, or M/C supervisors will address and manage them for proper corrections.	( )	( )	( )	( )	( )
A. Violations of SOP, NAMP guidelines or other procedures are discouraged in this command.	( )	( )	( )	( )	( )
15. Supervisors are more concerned with proper aircraft maintenance than mission completion and do not allow cutting corners to meet operational commitments.	( )	( )	( )	( )	( )

	Strongly Agree	Agree	Neutral/ Mixed	Disagree	Strongly Disagree
16. My supervisors are aware of individual daily workload requirements and recognize safety achievements through rewards and incentives.	( )	( )	( )	( )	( )
17. Supervisors communicate command safety goals, programs and procedures.	( )	( )	( )	( )	( )
18. W/C supervisors are respected by the maintenance chief/officer.	( )	( )	( )	( )	( )
19. Qualified personnel properly supervise all maintenance evolutions and maintainers are briefed on the potential hazards associated with maintenance activities.	( )	( )	( )	( )	( )
20. My supervisor shields me from outside pressures which may affect my work.	( )	( )	( )	( )	( )
21. QARs are never pressured by the maintenance supervisors to sign off a gripe.	( )	( )	( )	( )	( )
22. Maintainer staffing is sufficient, is equally worked and is equally stressed / fatigued from shift to shift.	( )	( )	( )	( )	( )
23. Multiple job assignments and collateral duties do not adversely affect maintenance.	( )	( )	( )	( )	( )
24. Personnel turnover does not affect my command's ability to operate safely.	( )	( )	( )	( )	( )
25. Violations of SOP, NAMP guidelines, or other procedures are not common in my command.	( )	( )	( )	( )	( )
26. Proper tools and equipment are available, serviceable and used and I am provided adequate resources (time, personnel) to accomplish my job.	( )	( )	( )	( )	( )
27. Maintenance Control never troubleshoots aircraft discrepancies.	( )	( )	( )	( )	( )
28. Required publications are available, current, and used.	( )	( )	( )	( )	( )
29. The QA division is respected and CDIs / QARs routinely monitor maintenance evolutions ensuring that maintenance gripes are either corrected or addressed prior to flight.	( )	( )	( )	( )	( )
30. Signing off PQS/JQRs/PARs is taken seriously, not gun decked and maintenance quality is as high on detachments as it is in homeport.	( )	( )	( )	( )	( )
31. Safety is an integral part of this command's maintenance planning/flight line operations, where QARs are helpful and the QA division is not "feared".	( )	( )	( )	( )	( )

	Strongly Agree	Agree	Neutral/ Mixed	Disagree	Strongly Disagree
32. Personnel are comfortable telling supervisors about personal problems including illness.	( )	( )	( )	( )	( )
33. I feel I get all information (internal and external) required to perform my job safely, and feel free to report safety violations, unsafe performance or other unsafe behavior.	( )	( )	( )	( )	( )
34. Maintainers are never purposely put in an unsafe situation to meet the flight schedule.	( )	( )	( )	( )	( )
35 Safety education and training in my command are comprehensive and effective and the safety department is respected by the supervisors and maintainers.	( )	( )	( )	( )	( )

APPENDIX B. DEMOGRAPHIC VARIABLE BAR CHARTS.

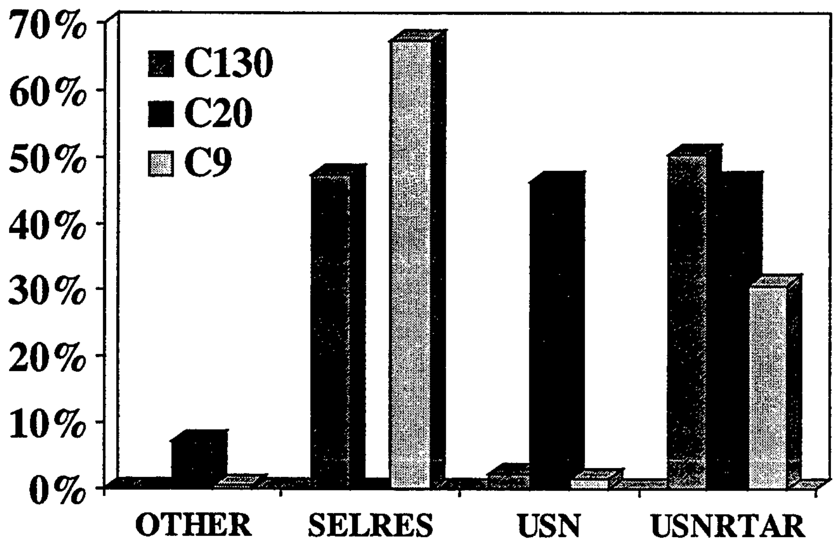

Figure 19. MCAS Respondent Service Type.

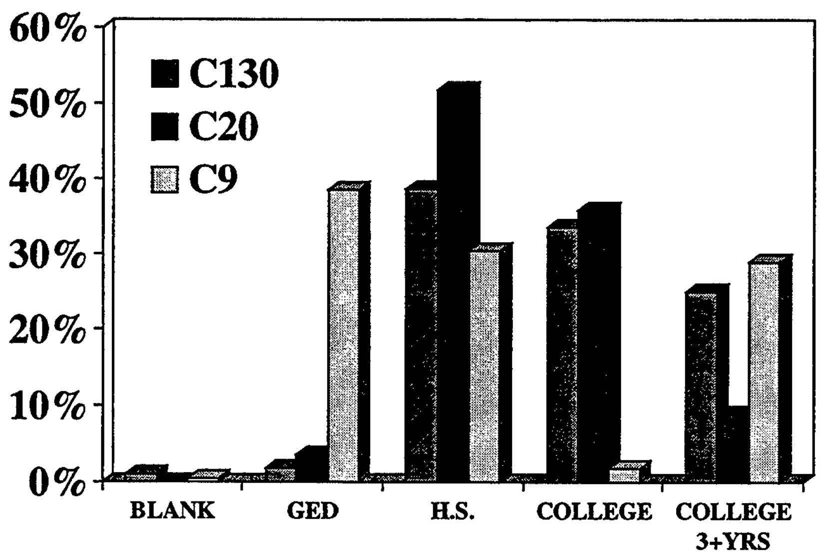

Figure 20. MCAS Respondent Education Level.

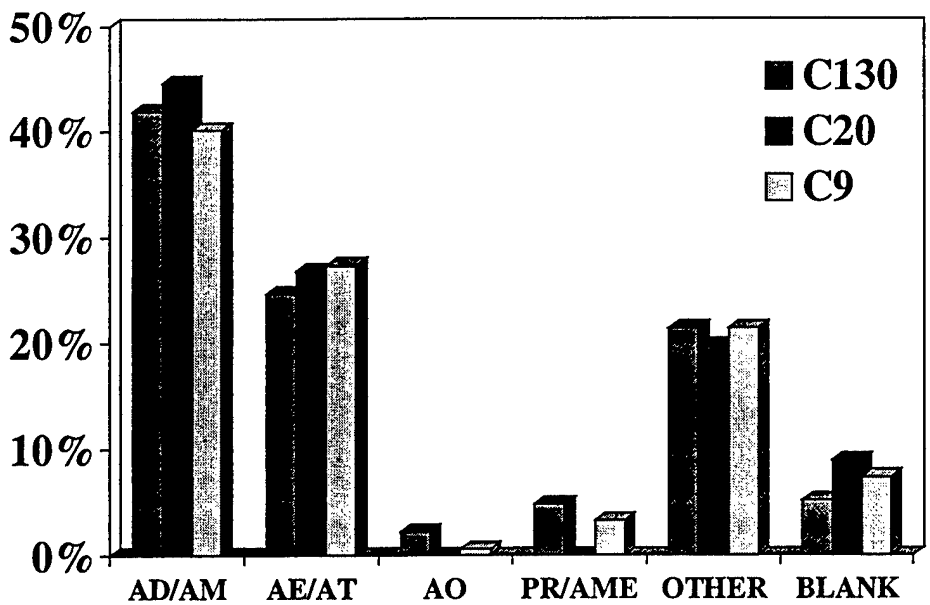

Figure 21. MCAS Respondent Rating.

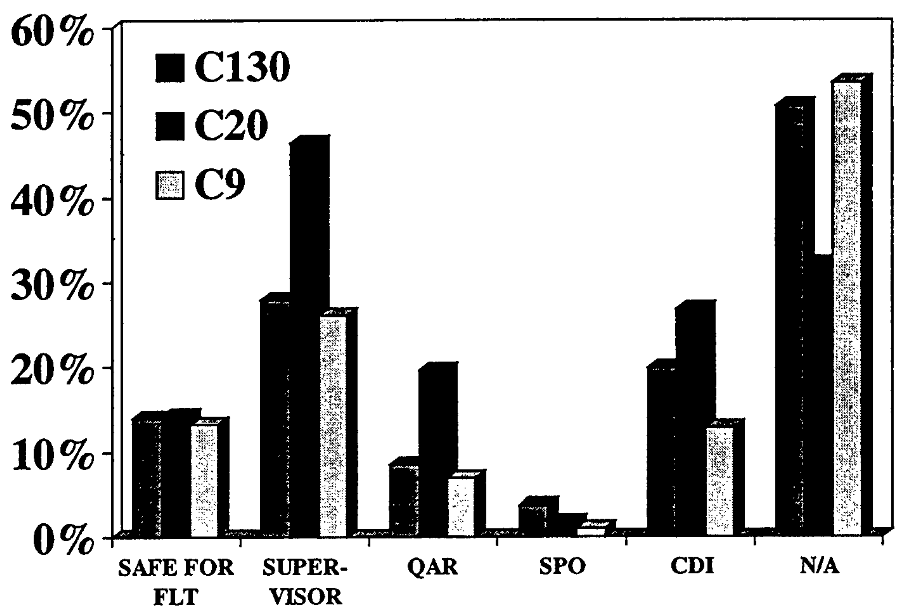

Figure 22. MCAS Respondent Current Maintenance Qualifications.

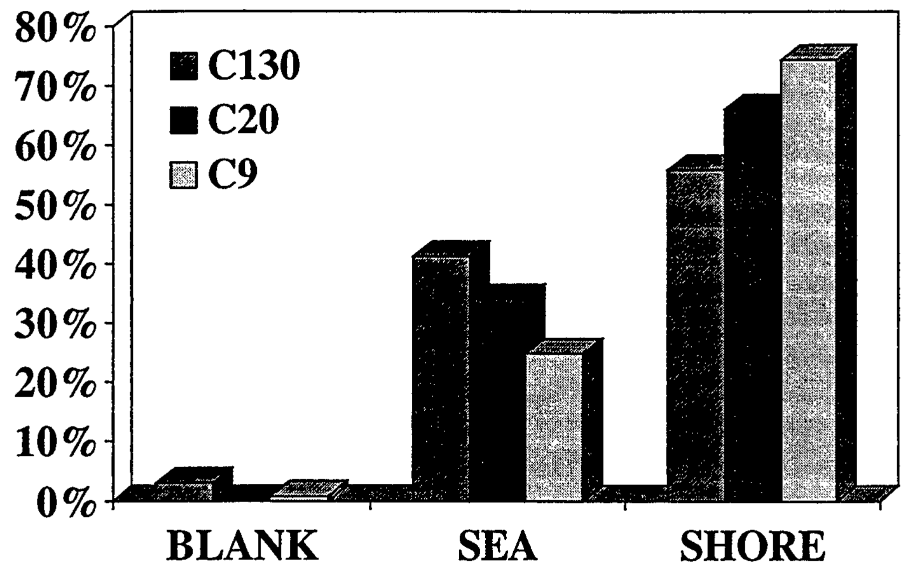

Figure 23. MCAS Respondent Duty Type.

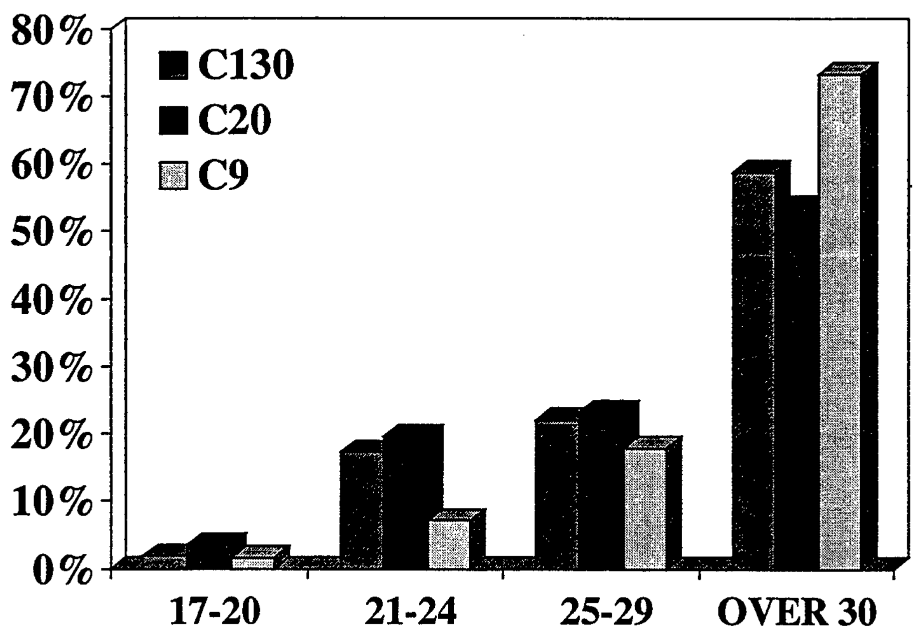

Figure 24. MCAS Respondent Age.

APPENDIX C. SURVEY QUESTION STANDARD DEVIATIONS

	Questions			
Community	**1**	**2**	**6**	**8**
C-130	0.96	0.84	0.77	0.88
C-20	0.94	0.83	0.84	0.98
C-9	0.86	0.68	0.75	0.88

Table 14. Process Auditing Standard Deviations.

	Questions				
Community	**4**	**13**	**14**	**25**	**32**
C-130	0.97	0.93	0.92	0.95	1.05
C-20	0.95	1.02	0.84	0.87	1.08
C-9	0.93	0.85	0.91	0.94	1.06

Table 15. Reward System Standard Deviations.

	Questions								
Community	**3**	**7**	**12**	**16**	**22**	**26**	**28**	**29**	**30**
C-130	0.91	0.96	0.85	1.02	1.11	1.06	1.10	0.83	0.98
C-20	0.95	1.00	0.67	1.17	1.23	1.11	0.94	0.79	0.96
C-9	0.79	0.92	0.73	0.99	1.08	1.06	1.09	0.74	0.98

Table 16. Quality Assurance Standard Deviations.

	Questions				
Community	**9**	**15**	**24**	**31**	**34**
C-130	1.14	1.03	1.11	0.86	1.11
C-20	1.14	1.10	1.18	0.83	1.11
C-9	1.08	0.91	1.09	0.90	0.94

Table 17. Risk Management Standard Deviations.

	Questions					
Community	**11**	**17**	**18**	**19**	**23**	**35**
C-130	1.01	0.85	1.10	0.87	1.03	0.90
C-20	1.05	0.85	1.16	0.85	1.05	0.99
C-9	0.90	0.80	0.98	0.85	1.11	0.83

Table 18. Command & Control Standard Deviations.

	Questions					
Community	**5**	**10**	**20**	**21**	**27**	**33**
C-130	1.07	1.09	1.00	1.07	1.08	0.94
C-20	1.07	1.17	1.01	1.07	1.11	1.11
C-9	1.05	1.02	0.97	0.95	1.16	0.79

Table 19. Communication/Functional Relationship Standard Deviations.

APPENDIX D. PROPOSED REVISED MCAS QUESTIONS

COMPONENT 1: PROCESS AUDITING

1. The command adequately reviews and updates safety practices.
2. The command monitors maintainer qualifications and has a program that targets training deficiencies.
3. The command uses safety and medical staff to identify/manage personnel at risk.
4. CDIs/QARs routinely monitor maintenance evolutions.
5. Tool Control is taken seriously in the command and support equipment licensing is closely monitored.
6. Signing of PQS/JQRs/PARs is taken seriously and not gundecked.

COMPONENT 2: REWARD SYSTEM and SAFETY CLIMATE

1. Our command climate promotes safe maintenance and flight operations.
2. Supervisors discourage SOP, NAMP guideline, or other procedure violations and encourage reporting safety concerns without fear of retribution.
3. Peer influence discourages SOP, NAMP guideline, or other procedure violations and individuals feel free to report safety violations, unsafe performance, or unsafe behaviors.
4. Violations of SOP, NAMP guidelines, or other procedures are not common in this command.
5. The command recognizes individual safety achievement through rewards and incentives.
6. Personnel are comfortable approaching supervisors about personal issues/illness.
7. Maintenance Safety Petty Officer, Quality Assurance Representative, and Collateral Duty Inspector are sought after billets in the command.
8. Unprofessional behavior is not tolerated in the command.

COMPONENT 3: QUALITY ASSURANCE

1. The command has a reputation for quality maintenance and has set standards to maintain quality control.
2. The QA Division and Safety Department are respected in the command and are seen as essential to mission accomplishment.
3. QARs/CDIs perform all required actions before sign-off and are never pressured by maintenance supervisors.
4. Maintenance quality on detachments is the same as that at home station.
5. Required publications/tools/equipment are available, current/serviceable, and are exclusively used.
6. QARs are viewed as helpful, and QA is not "feared" in my command.

COMPONENT 4: RISK MANAGEMENT

1. Multiple job assignments and collateral duties adversely affect maintenance.
2. Safety is part of maintenance planning, and additional training/support is provided as needed.
3. Supervisors recognize unsafe conditions and manage the hazards associated with maintenance and flight line operations.
4. I am provided adequate resources (time, personnel and equipment) to accomplish my job.
5. Personnel turnover does not negatively impacts the command's ability to operate safely.
6. Supervisors are more concerned with safely conducting aircraft maintenance than meeting flight schedule, and do not permit cutting corners or purposely putting maintainers in unsafe situations.
7. Maintainer staffing is sufficient from shift to shift, and Day/Night Check have proportionately stressful/fatiguing workloads.
8. Supervisors shield personnel from outside pressures that may affect their work, and are aware of individual workload and personal issues.
9. Based upon my command's current manning/assets, it is not over-committed

COMPONENT 5: COMMAND AND CONTROL

1. My command temporarily restricts maintainers who are having personal problems.
2. Safety decisions are made at the proper command levels, and CC W/C supervisors are respected by the maintenance chief/officer.
3. Supervisors communicate command safety goals, programs, and procedures, and are actively involved in the safety program and management of safety matters.
4. Supervisors set the example for compliance to maintenance standards and ensure uniform enforcement of SOPs, NAMP guidelines, and other procedures among maintenance personnel.
5. In my command, safety is an integral part of all maintenance and flight line operations and all maintainers are responsible and accountable for safe maintenance.
6. Safety education and training in my command are comprehensive and effective.
7. All maintenance evolutions are properly briefed, supervised, and staffed by qualified personnel, including flight line activities such as aircraft moves.
8. Maintenance control is effective in managing all maintenance activities.

COMPONENT 6: COMMUNICATION / FUNCTIONAL RELATIONSHIPS

1. Good communication flow exists up and down the chain of command and I get all the information required to perform my job safely.
2. Work center supervisors, division CPOs, QA, and M/C coordinate their actions, including the incorporation of TDs.
3. My command has effective pass-down between shifts.

4. Maintenance Control always troubleshoots aircraft discrepancies and gripes are either corrected or addressed prior to flight.
5. Maintainers are briefed on potential hazards associated with maintenance activities.

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